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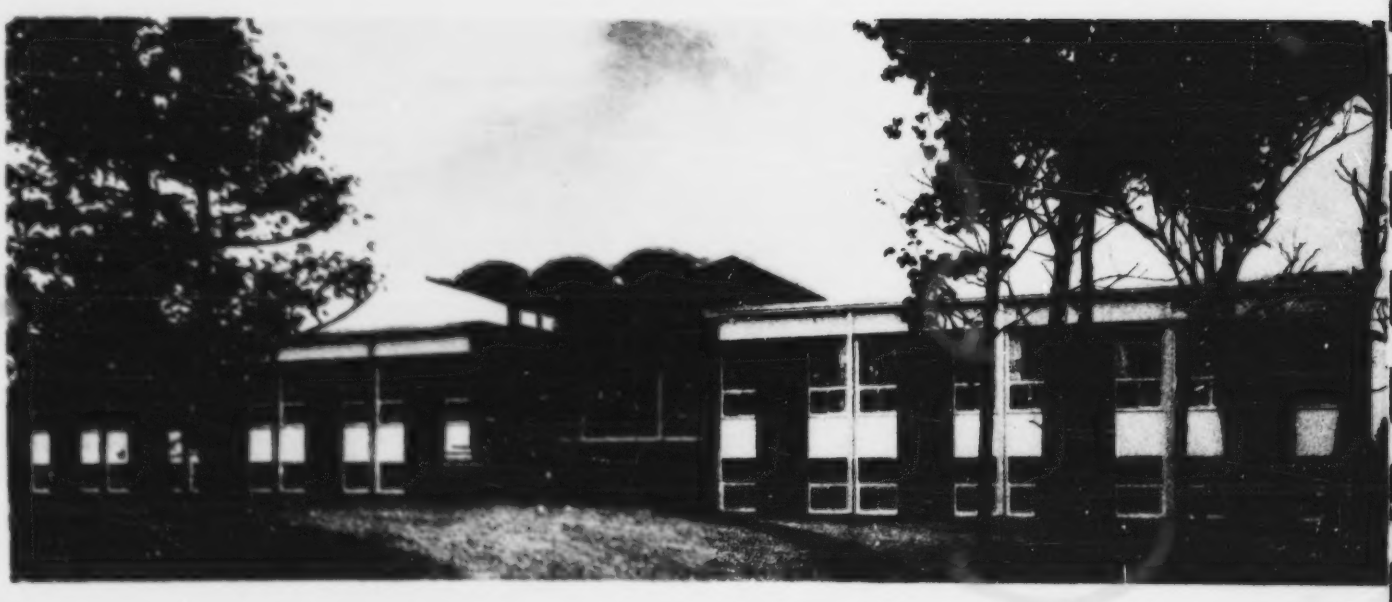

EFFECT OF TEMPERATURE AND HYDROGEN PRESSURE ON LIQUID YIELDS FROM SELECTED OIL SHALES

Final Report

By

Mineral Development and Processing
The Research and Productivity Council

Work on the project was conducted under the auspices of the Canada Center for Mineral and Energy Technology, Energy, Mines and Resources, Canada.

DSS File Number : 07SQ.23440-4-9066
DSS Contract Number : 0SQ84-00088
CANMET Scientific Authority : Dr. E. Furimsky

April 3, 1985
Report Number MDP/84/103

OCT 11 1985

100 pp

MICROMEDIA

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1.0 SUMMARY

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A total of five oil shale samples from Eastern Canada were evaluated using Fischer Assay Retort and hydrogen retort methods. For all shales, the presence of hydrogen during retorting resulted in increased yields compared to Fischer Assay yields.

The five oil shales were evaluated at selected hydrogen pressures, retorting temperatures and heating rates. Generally increasing hydrogen pressures during retorting had little affect on oil yields while increasing retorting temperatures increased oil yields significantly. Higher gas yields at increased retorting temperatures were partially attributed to the generation of CO_2 from the dissociation of mineral carbon.

Nitrogen content in oil products was found to increase in the presence of hydrogen. This was attributed to the stabilization of reactive intermediates by hydrogen. Sulphur content in oil products was found to decrease in the presence of hydrogen. This decrease was believed to be the result of increased sulphur in the gaseous products.

2.0 RECOMMENDATIONS

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It is recommended that the response of selected Canadian oil shales to steam pyrolysis be examined. Since hydrogen gas is an expensive commodity the benefaction of oil shales with steam may be more economical. It would be possible to test steam pyrolysis of oil shales on the existing test facility with minor modifications.

3.0 INTRODUCTION

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3.1 General

The oil shales from Eastern Canada are deficient in hydrogen with the result when heated for the Fischer assay or conventional retorting process, the hydrogen-poor kerogen is converted to coke. The full potential of Eastern oil shales in terms of energy recovery can be only attained by retorting under hydrogen pressure. Coking is reduced and yields of oil and hydrocarbon gases are increased.

The Research and Productivity Council, under the guidance and funding of Energy, Mines and Resources, CANMET, has been investigating the concept of hydrogen retorting as a means of increasing the recovery of oil from Canadian oil shales.

Under the first phase of the work in 1981[1], RPC developed a hydrogen retort facility for testing the retorting behaviour of oil shales. During the second phase of work in 1982[2], hydrogen retorting conditions were optimized using a Kentucky shale sample. Thirty-seven oil shales from New Brunswick, Ontario, Newfoundland, British Columbia and Quebec were evaluated. The results showed that the presence of hydrogen during pyrochem retorting resulted in a significant increase in oil yields compared to Fischer assay yields. Also, the quality of liquid products was affected by the presence of H_2. Particularly, the specific gravity of the products from hydrogen retorting was lower than that of products from retorting in the absence of hydrogen.

3.2 Contract Objectives

The objective of the test program was to determine the effect of temperature and hydrogen pressure on liquid product yields from five oil shale samples.

A total of five shale samples (two from New Brunswick, two from Ontario and one from Newfoundland) were obtained and prepared for testing. Each raw shale was characterized and retorted using the Fischer assay technique. Shale samples were then hydrogen retorted at different hydrogen pressures, final temperatures and heating rates. All spent shale samples and liquid products from the Fischer assay and hydrogen retort testing were characterized. Finally, all experimental results were tabulated and evaluated to determine trends and correlations. (A detailed "Statement of Work" can be found in Appendix 9.1.)

4.0 EXPERIMENTAL

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4.1 Modifications to Hydrogen Retorting Apparatus

Several modifications were made to the existing retorting apparatus used in the previous program[2].

An Applied Test Systems Series 3210 Split Type Oven was added to heat the retort unit. It was mounted vertically on a double hinge to allow swinging the oven out of the way during assembly of the apparatus and provide centring of the retort during testing. The retort section was rebuilt to match the oven and the placement of the thermocouples. The preheater/superheater retained its heating coils as its heating source. It was rebuilt, utilizing a lathe to wind the heating coils tightly to give better heat transfer and a more efficient unit.

Both the oven and preheater/superheater coils were heated by PID type control systems. These consisted of a Halmar type LZF1 Power Controller driven by an Omega Series 2010 PID Controller. These heating systems allowed a rate programming of up to 25^{o}C per minute.

In addition, glassware modifications were made to improve liquid recoveries. All grease fittings were replaced with greaseless fittings with teflon O rings. The collection tube was replaced with a modified centrifuge tube to eliminate any losses during the transfer before centrifuging.

4.2 Experimental Procedures

The experimental procedure developed during the previous test program[2] was followed for the hydrogen

retcrting testing. A detailed outline of the procedure can be found in Appendix 9.2.

Briefly, approximately 75 gms of crushed (- 6 to + 18) dried (105°C) shale was weighed and placed in the retort. The retort was assembled and checked for leaks. The condenser was assembled and ice and liquid N_2 were added to the traps. The system was pressurized to the desired pressure and the flow was set. The retort was heated at the desired rate to the final temperature with the programmable controllers. Heating was continued at the final temperature for the additional 30 minutes.

The retort was cooled and samples were weighed and sealed in containers for analyses.

The U. S. Bureau of Mines method RI3997 was used for the Fischer assay retorting. Approximately 100 g of accurately weighed shale was heated from room temperature to 500°C at 12°C/min. Heating was continued at this temperature for another 40 minutes. The liquid products were trapped in a volume-calibrated trap immersed in ice water.

ASTM methods were used for the proximate analysis. Moisture was determined at 105°C, ash at 750°C and volates at 950°C. Analysis of carbon and sulphur for solid samples were performed on an LECO C-S analyzer. The content of organic carbon was obtained by digesting carbonate carbon with HCl and analyzing the remaining carbon. Mineral carbon was obtained by subtracting organic carbon from total carbon. Carbon and hydrogen for liquid samples and nitrogen for all samples were analyzed on a CHN analyzer. Metallic content of the shales (Fe, Al, Ca, Mg, K, Na) was determined using a

$HCL-HNO_3$-HF digest and atomic absorption. Silicon was determined gravimetrically using an Na_2CO_3 fusion.

4.3 Sample Selection

A total of 5 samples were procured for testing through consultations with the Scientific Authority. Two samples were obtained from the Albert formation in New Brunswick, one shale from the Deer Lake-Humber River formation in Newfoundland and two samples from the Collingwood formation in Ontario. Additional information can be found in Appendix 9.3. Each sample was carefully crushed to obtain approximately 5 kg of -6 + 18 mesh material. The samples were well mixed and sealed in plastic bags until testing.

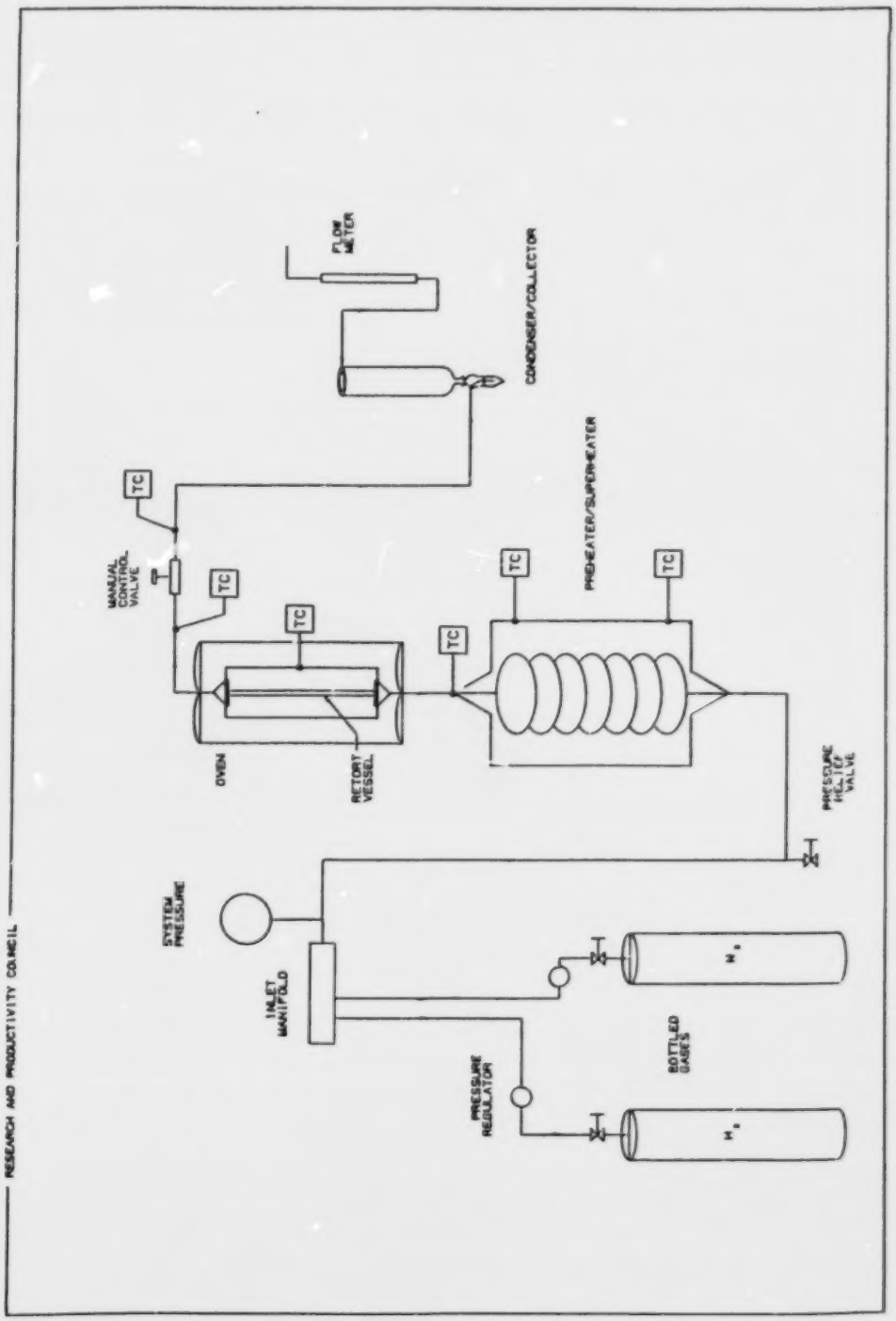


Figure 1: Schematic Diagram of the RPC Hydrogen Retort Apparatus

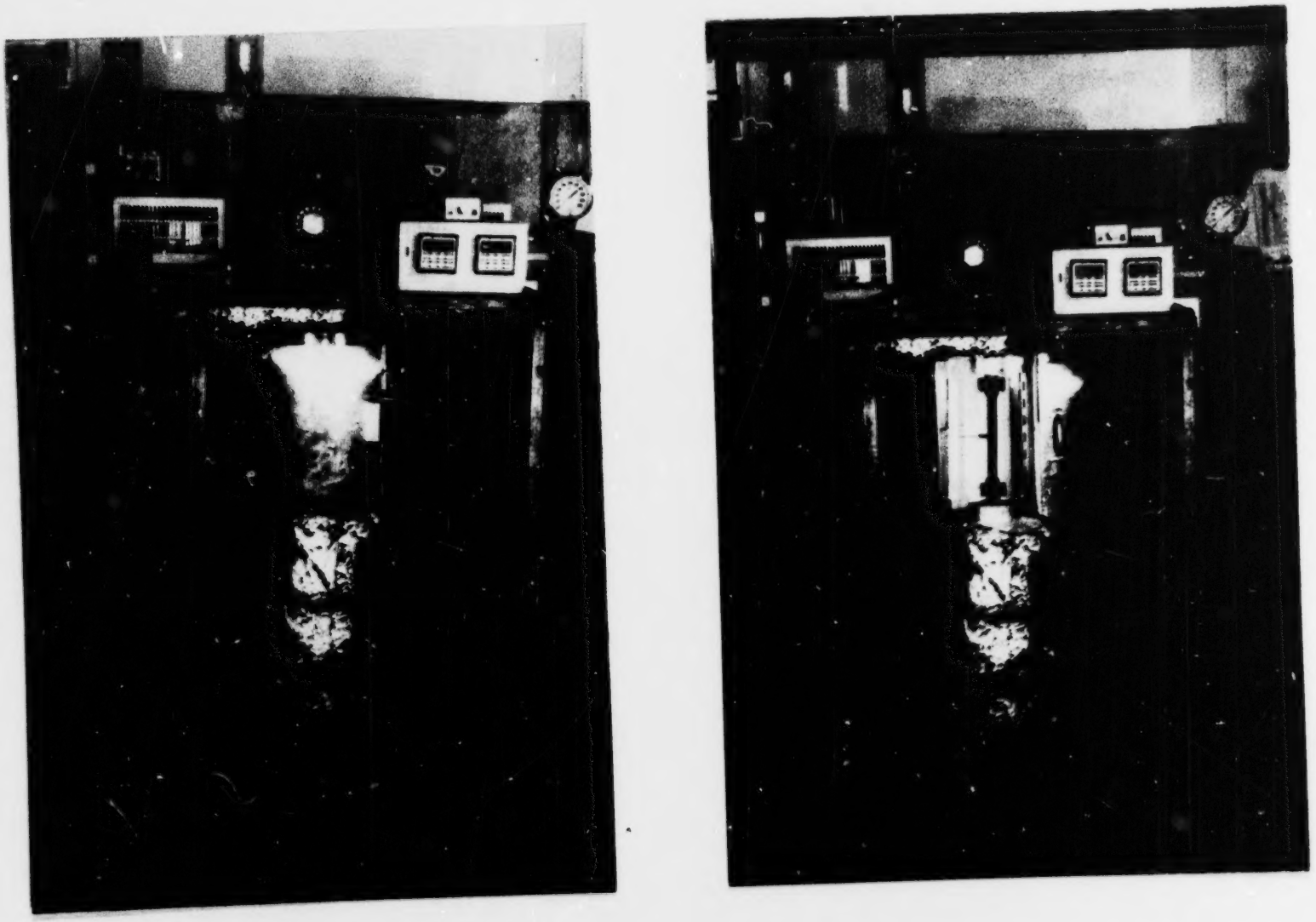
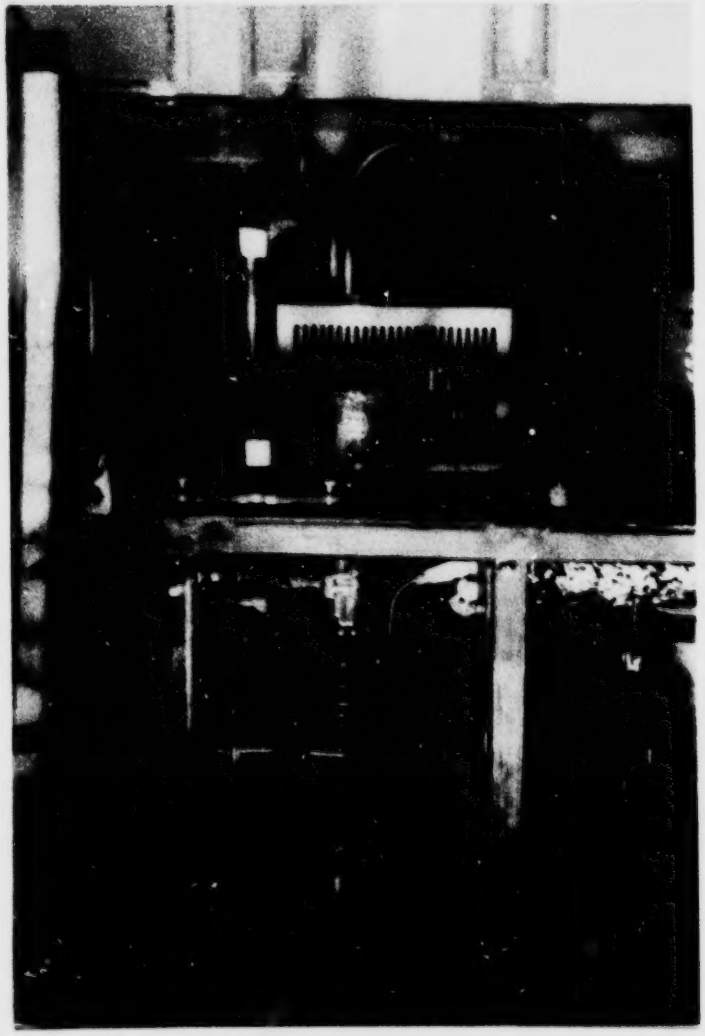


Figure 2: Photographs of Hydrogen Retort Apparatus



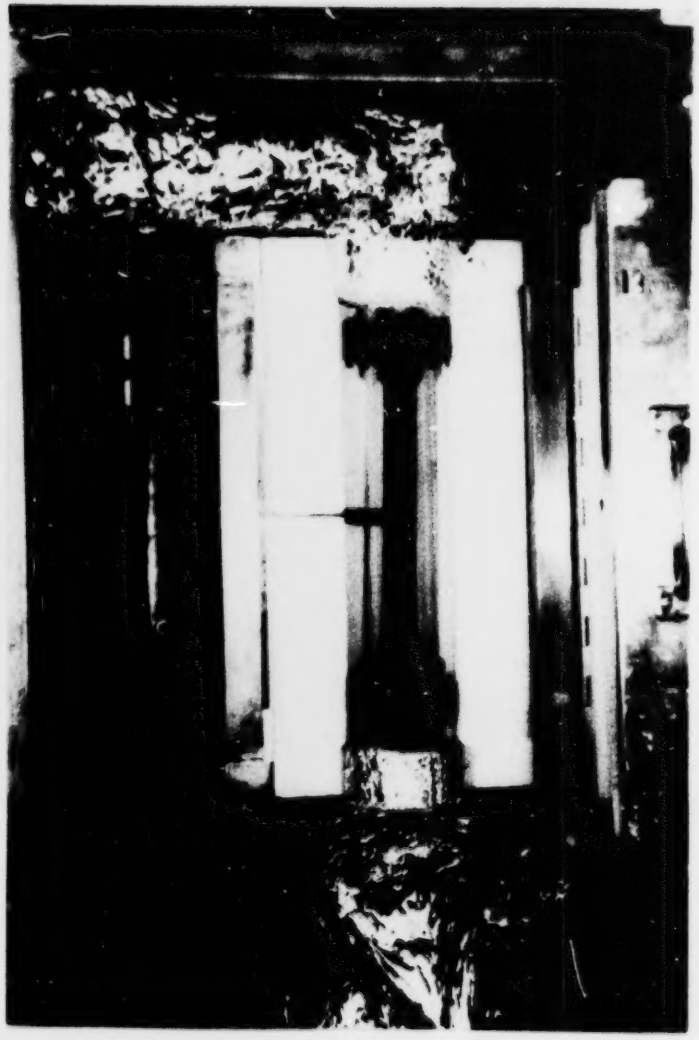


Figure 3: Photographs of Glassware and Retort Vessel

5.0 RESULTS AND DISCUSSIONS

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The results of the proximate and ultimate analyses for the five oil shales are given in Table 1 and the metallic oxide compositions can be found in Table 2.

The organic carbon content in oil shales usually reflects the amount of kerogen in the shales and can be related to the oil yields of the retorted shales. The Fischer assay results of the five shales are given in Table 3. The linear correlation between the Fischer assay oil yields and organic carbon content can be found in Figure 4. Elemental analysis of the spent shales and the liquid products from the Fischer assays are recorded in Tables 4 and 5.

Results of the hydrogen retorted oil shales at various hydrogen pressures, final temperatures and heating rates can be found in Tables 6, 7, 8, 9, 10 for New Brunswick 1, New Brunswick 2, Newfoundland 189-10, Ontario OGS-83-3 and Ontario OGS-83-5 respectively. Generally retorting in the presence of hydrogen increased oil yields compared to Fischer retorting. This is evident from the higher slope of the line in Figure 5 for hydrogen retort oil yields vs organic carbon than for Fischer assay oil yields vs organic carbon (hydrogen retort results at 500^{o}C, 0 psi hydrogen and 12^{o}C/minute rate). Increasing hydrogen pressures from 0 psi to 500 psi had little affect on oil yields as shown by Figures 6, 7, 8, 9 and 10. Of the three samples retorted at 800 psi hydrogen, the two Ontario samples showed increased gas yields at the higher pressures. This could have been the result of increased cracking of the liquid products to gaseous products at the higher pressure. Figures 11 to 15 show trends of hydrogen retorting of shales with increasing

final temperatures. Generally all shales exhibited significant increases of liquid products at higher temperatures.

The elemental analysis of the spent shales from hydrogen retorting testing are given in Tables 11 to 15. Organic carbon in spent shales from hydrogen retorting were generally lower than organic carbon in spent shales from Fischer assay supporting the higher liquid yields reported in retorting with hydrogen.

In addition, increasing hydrogen pressures did not affect organic carbon in spent shales while increasing final retorting temperatures decrease organic carbon in spent shales. Those trends shown in Figures 16 to 20 for pressure vs organic carbon and Figures 21 to 25 for temperature vs organic carbon confirm the relationship previously stated for liquid and gaseous yield; i.e. yields were not affected by hydrogen pressure and increased with final temperature.

The effects of increasing final temperatures on mineral carbon in the spent shales are shown in Figures 26 to 30. Decreasing mineral carbon at the higher temperatures was the result of $CaCO_3$ and $MgCO_3$ decomposing to form the respective oxides and CO_2. This indicates that the increased gas yields at high temperatures found in Figures 11 to 15 are only partially due to kerogen conversion to light hydrocarbons.

Nitrogen content in spent shales was generally lower than in raw shales. Hydrogen pressures had little affect on nitrogen content in spent shales but increasing final temperatures decreased nitrogen content. Nitrogen analysis of oil products found in Tables 16 to 20 support the above trends with increased

nitrogen in oils at higher temperatures. This was attributed to the stabilization of precursors to nitrogen compounds which prevented polymerization to high molecular weight species.

Sulphur in oil products decreased significantly in hydrogen retorted samples compared to Fischer assayed samples, however, spent shales from hydrogen retorted samples did not show increases in sulphur content compared to Fischer assayed spent shales. This may indicate increased sulphur in gaseous products. Increased hydrogen pressures and increased retorting temperatures had little effect on sulphur in spent shales or liquid products.

TABLE 1: ELEMENTAL ANALYSIS OF OIL SHALES

Sample	Total Carbon (wt%)	Organic Carbon (wt%)	Mineral Carbon (wt%)	Hydrogen (wt%)	Sulphur (wt%)	Nitrogen (wt%)	Oxygen (wt%)	Ash (wt%)	Moisture (wt%)	Volatiles (wt%)
New Brunswick 1	14.6	11.2	3.4	2.35	0.76	0.47	8.0	73.8	0.94	24.7
New Brunswick 2	11.5	10.3	1.2	1.51	0.55	0.32	4.4	81.5	0.33	20.6
Newfoundland 189-10	10.0	4.9	6.1	0.90	0.14	0.11	15.3	73.5	0.51	23.0
Ontario OGS-83-3	9.0	5.0	4.0	0.83	1.73	0.19	8.1	80.3	0.46	20.0
Ontario OGS-83-5	13.0	4.7	8.3	0.78	0.82	0.15	21.2	64.4	0.26	34.4

TABLE 2: METAL OXIDE ANALYSIS OF OIL SHALES

Sample	SiO_2 (wt%)	Fe_2O_3 (wt%)	Al_2O_3 (wt%)	CaO (wt%)	MgO (wt%)	Na_2O (wt%)	K_2O (wt%)	Loss on Ingition
New Brunswick 1	55.29	5.94	17.08	11.34	3.50	2.10	1.87	1.26
New Brunswick 2	58.98	6.08	16.26	7.47	1.43	4.51	2.27	1.80
Newfoundland 189-10	49.63	3.80	8.90	18.67	15.40	2.13	1.10	0.80
Ontario OGS-83-3	51.37	6.52	18.96	10.51	2.81	1.54	2.89	3.86
Ontario OGS-83-5	24.41	2.46	6.62	41.8	4.04	1.53	1.27	3.64

TABLE 3: FISCHER ASSAY OF OIL SHALES

Sample	Water Yield (wt%)	Gas Yield (wt%)	Oil Yield (wt%)	Density g/ml @ 15.5°C	Litre/ Metric Ton
New Brunswick 1	2.3	1.9	8.3	0.8706	95.3
New Brunswick 2	1.5	2.3	6.2	0.8913	69.6
Newfoundland 189-10	1.0	1.1	3.4	0.8819	38.6
Ontario OGS-83-3	0.7	1.2	2.1	0.8834	23.8
Ontario OGS-83-5	0.3	1.7	2.5	0.9038	27.7

TABLE 4: ELEMENTAL ANALYSIS OF SPENT SHALES FROM FISCHER

ASSAYED SAMPLES

Sample	Total Carbon (wt%)	Organic Carbon (wt%)	Mineral Carbon (wt%)	Hydrogen (wt%)	Sulphur (wt%)	Nitrogen (wt%)	Oxygen (wt%)	Ash (wt%)	Moisture (wt%)	Volatiles (wt%)
New Brunswick 1	6.94	4.16	2.78	0.44	0.77	0.26	6.79	84.8	0.05	13.6
New Brunswick 2	6.31	4.50	1.81	0.34	0.56	0.24	3.35	89.2	0.04	12.2
Newfoundland 189-10	7.11	1.65	5.46	0.30	0.29	0.07	15.23	77.0	0.06	21.2
Ontario OGS-85-3	6.93	3.52	3.41	0.45	1.64	0.15	8.73	82.1	0.03	18.2
Ontario OGS-83-5	10.87	3.76	7.11	0.22	0.57	0.12	21.72	66.5	0.05	32.4

TABLE 5: ELEMENTAL ANALYSIS OF OILS FROM FISCHER ASSAYS

Sample	Carbon (wt%)	Hydrogen (wt%)	Sulphur (wt%)	Nitrogen (wt%)	Oxygen (wt%)
New Brunswick 1	85.01	11.89	1.62	0.94	0.54
New Brunswick 2	84.87	11.44	1.42	1.22	1.05
Newfoundland 189-10	85.26	11.29	0.98	1.09	1.38
Ontario OGS-83-3	85.30	11.74	1.05	0.51	1.40
Ontario OGS-83-5	84.34	10.58	2.35	0.90	1.83

TABLE 6: HYDROGEN RETORT OF NEW BRUNSWICK
1 OIL SHALE

Sample	Hydrogen Pressure psi	Final Temperature ^{o}C	Heating Rate ^{o}C/min	Water wt%	Gas wt%	Oil wt%	Density g/ml	Oil L/Tonne
HR 45	0	500	12	1.9	1.7	9.9	0.8556	115.7
HR 24	100	500	12	1.8	3.1	7.7	0.8611	89.4
HR 19	300	500	12	1.8	3.8	7.5	0.8333	90.0
HR 37	500	500	12	1.4	2.5	9.3	0.8556	108.7
HR 57	100	400	12	1.0	1.6	3.3	0.8000	41.3
HR 24	100	500	12	1.8	3.1	7.7	0.8611	89.4
HR 58	100	600	12	3.6	4.2	8.1	0.8556	94.7
HR 59	100	700	12	4.5	7.5	12.3	0.8056	152.7
HR 68	100	700	6	4.7	7.1	12.2	0.8056	151.7

Note: Samples at 0 pressure H_2 were run in the presence of hydrogen (i.e. one atmosphere H_2).

TABLE 7: HYDROGEN RETORT OF NEW BRUNSWICK 2 OIL SHALE

Sample	Hydrogen Pressure psi	Final Temperature ^{o}C	Heating Rate ^{o}C/min	Water wt%	Gas wt%	Oil wt%	Density g/ml	Oil L/Tonne
HR 15	0	500	12	1.8	0.6	8.2	0.8278	99.1
HR 43	100	500	12	1.2	3.5	7.3	0.8444	86.5
HR 35	300	500	12	1.6	3.3	7.4	0.8333	88.8
HR 36	500	500	12	1.5	3.8	6.9	0.8667	79.6
HR 66	100	400	12	1.0	1.6	2.4	0.9000	26.7
HR 43	100	500	12	1.2	3.2	6.9	0.8444	81.7
HR 67	100	600	12	2.3	3.8	8.4	0.8667	96.9
HR 62	100	700	12	2.7	6.0	9.9	0.8444	117.2
HR 70	100	700	6	3.2	4.8	10.8	0.8111	133.6

TABLE 8: HYDROGEN RETORT OF NEWFOUNDLAND
189-10 OIL SHALE

Sample	Hydrogen Pressure psi	Final Temperature °C	Heating Rate °C/min	Water wt%	Gas wt%	Oil wt%	Density g/ml	Oil L/Tonne
HR 32	0	500	12	0.4	1.0	3.9	0.8111	48.1
HR 33	100	500	12	0.1	1.3	4.1	0.8333	49.2
HR 81	300	500	12	0.7	1.5	3.0	0.8889	33.7
HR 34	500	500	12	0.8	1.5	3.0	0.8556	35.1
HR 63	800	500	12	0.8	1.0	3.5	0.8500	41.2
HR 80	300	400	12	0.0	1.0	1.4	--	16.3*
HR 81	300	500	12	0.7	1.2	3.0	0.8889	33.7
HR 82	300	600	12	1.8	3.3	4.0	0.8556	46.8
HR 83	300	700	12	7.1	8.9	3.2	0.8944	35.8
HR 86	300	700	6	5.9	9.2	5.0	0.8667	57.9

* Based on Density of 0.8597

-- Density not available

TABLE 9: HYDROGEN RETORT OF ONTARIO
OGS-83-3 OIL SHALE

Sample	Hydrogen Pressure psi	Final Temperature °C	Heating Rate °C/min	Water wt%	Gas wt%	Oil wt%	Density g/ml	Oil L/Tonne
HR 29	0	500	12	0.1	2.3	2.2	--	24.4*
HR 30	100	500	12	0.5	1.9	2.5	--	27.8*
HR 77	300	500	12	0.8	2.2	2.3	--	25.6*
HR 31	500	500	12	0.0	3.4	1.6	--	17.8*
HR 65	800	500	12	0.5	4.9	1.8	0.9000	20.0
HR 71	300	400	12	0.0	1.6	0.6	--	6.7*
HR 77	300	500	12	0.8	1.3	2.4	--	26.7*
HR 73	300	600	12	2.8	3.9	2.6	0.9000	28.9
HR 74	300	700	12	5.6	8.8	1.6	--	17.8*
HR 85	300	700	6	4.5	7.3	2.7	0.8800	30.9

* Based on Density of 0.9000

-- Density not available

TABLE 10: HYDROGEN RETORT OF ONTARIO
OGS-83-5 OIL SHALE

Sample	Hydrogen Pressure psi	Final Temperature °C	Heating Rate °C/min	Water wt%	Gas wt%	Oil wt%	Density g/ml	Oil L/Tonne
HR 27	0	500	12	0.1	1.1	3.3	--	38.0*
HR 38	100	500	12	0.3	1.8	2.6	0.9000	28.9
HR 76	300	500	12	0.3	1.9	3.0	0.8571	35.0
HR 28	500	500	12	0.0	1.9	3.3	--	38.0*
HR 64	800	500	12	0.3	3.2	1.6	0.8600	20.0
HR 75	300	400	12	0.1	0.4	1.3	--	15.0*
HR 76	300	500	12	0.3	1.9	3.0	0.8571	35.0
HR 78	300	600	12	1.4	2.9	3.6	--	41.4*
HR 79	300	700	12	2.8	9.2	5.3	--	61.0*
HR 84	300	700	6	3.1	8.9	5.6	0.8722	64.2

* Based on Density of 0.8686

-- Density not available

TABLE 11: ELEMENTAL ANALYSIS OF SPENT SHALES FROM HYDROGEN RETORT OF NEW BRUNSWICK 1 SHALE

Sample	Hydrogen Pressure psi	Final Temp. °C	Heating Rate °C/min	Total Carbon (wt%)	Organic Carbon (wt%)	Mineral Carbon (wt%)	Sulphur (wt%)	Nitrogen (wt%)	Ash (wt%)	Moisture (wt%)	Volatiles (wt%)
HR 45	0	500	12	6.76	3.86	2.90	0.80	0.232	85.4	<0.10	12.6
HR 24	100	500	12	6.73	4.15	2.58	0.67	0.286	93.8	<0.10	13.2
HR 19	300	500	12	5.29	2.97	2.32	0.71	0.291	86.6	<0.10	11.6
HR 37	500	500	12	5.81	2.36	3.45	0.83	0.244	86.2	<0.10	14.4
HR 57	100	400	12	11.33	9.07	2.26	0.86	0.437	78.7	<0.10	17.9
HR 24	100	500	12	6.73	4.15	2.58	0.67	0.286	93.8	<0.10	13.2
HR 58	100	600	12	5.98	3.94	2.04	0.72	0.136	89.2	<0.10	9.9
HR 59	100	700	12	3.60	3.52	0.08	0.85	0.103	98.4	<0.10	0.4
HR 68	100	700	6	3.12	2.74	0.38	1.03	0.081	99.3	<0.10	0.4

TABLE 12: ELEMENTAL ANALYSIS OF SPENT SHALES FROM HYDROGEN RETORT OF NEW BRUNSWICK 2 SHALE

Sample	Hydrogen Pressure psi	Final Temp. °C	Heating Rate °C/min	Total Carbon (wt%)	Organic Carbon (wt%)	Mineral Carbon (wt%)	Sulphur (wt%)	Nitrogen (wt%)	Ash (wt%)	Moisture (wt%)	Volatiles (wt%)
HR 15	0	500	12	4.84	3.82	1.02	0.58	0.257	91.2	0.11	8.7
HR 43	100	500	12	5.09	3.53	1.56	0.45	0.244	90.5	<0.10	7.1
HR 35	300	500	12	4.13	2.98	1.15	0.84	0.141	91.8	<0.10	7.4
HR 36	500	500	12	4.32	2.18	2.14	0.76	0.167	92.4	<0.10	8.3
HR 66	100	400	12	9.69	8.78	0.91	0.98	0.290	85.1	<0.10	13.3
HR 43	100	500	12	5.09	3.53	1.56	0.45	0.244	90.5	<0.10	7.1
HR 67	100	600	12	4.16	3.11	1.05	0.70	0.131	94.4	<0.10	4.1
HR 62	100	700	12	3.14	2.94	0.20	0.59	0.076	99.1	<0.10	0.3
HR 70	100	700	6	2.58	2.57	<0.1	1.12	0.066	99.8	<0.10	0.7

TABLE 13: ELEMENTAL ANALYSIS OF SPENT SHALES FROM HYDROGEN RETORT OF NEWFOUNDLAND 189-10 SHALE

Sample	Hydrogen Pressure psi	Final Temp. °C	Heating Rate °C/min	Total Carbon (wt%)	Organic Carbon (wt%)	Mineral Carbon (wt%)	Sulphur (wt%)	Nitrogen (wt%)	Ash (wt%)	Moisture (wt%)	Volatiles (wt%)
HR 32	0	500	12	6.64	1.60	5.04	0.20	0.060	77.9	<0.10	21.4
HR 33	100	500	12	6.71	1.55	5.16	0.08	0.052	78.1	<0.10	20.4
HR 81	300	500	12	7.22	3.38	3.84	0.12	0.054	77.5	<0.10	20.6
HR 34	500	500	12	7.07	1.12	5.95	0.12	0.047	77.6	<0.10	21.2
HR 63	800	500	12	6.18	1.55	4.63	0.18	0.046	77.8	0.29	20.5
HR 80	300	400	12	9.32	3.72	5.60	0.18	0.081	75.4	<0.10	23.7
HR 81	300	500	12	7.22	3.38	3.84	0.12	0.054	77.5	<0.10	20.6
HR 82	300	600	12	6.06	2.84	3.22	0.06	0.039	81.1	<0.10	17.4
HR 83	300	700	12	3.72	1.70	2.02	0.05	0.027	91.1	<0.10	7.0
HR 86	300	700	6	2.80	1.62	1.18	0.04	0.027	92.0	<0.10	6.5

TABLE 14: ELEMENTAL ANALYSIS OF SPENT SHALES FROM HYDROGEN RETORT OF ONTARIO OGS-83-3 SHALE

Sample	Hydrogen Pressure psi	Final Temp. °C	Heating Rate °C/min	Total Carbon (wt%)	Organic Carbon (wt%)	Mineral Carbon (wt%)	Sulphur (wt%)	Nitrogen (wt%)	Ash (wt%)	Moisture (wt%)	Volatiles (wt%)
HR 29	0	500	12	6.26	3.51	2.75	1.37	0.163	83.2	<0.10	15.8
HR 30	100	500	12	6.59	3.23	3.36	1.28	0.164	82.9	<0.10	15.8
HR 77	300	500	12	6.62	3.30	3.32	1.32	0.140	83.4	<0.10	15.4
HR 31	500	500	12	6.19	3.03	3.16	1.38	0.142	83.2	<0.10	14.2
HR 65	800	500	12	6.43	2.92	3.51	1.11	0.109	84.6	<0.10	13.1
HR 71	300	400	12	8.47	5.12	3.35	1.26	0.186	81.5	<0.10	16.5
HR 77	300	500	12	6.62	3.30	3.32	1.32	0.140	83.4	<0.10	15.4
HR 73	300	600	12	5.86	3.07	2.79	1.35	0.100	88.0	<0.10	11.9
HR 74	300	700	12	4.56	2.82	1.74	2.53	0.069	95.8	<0.10	5.8
HR 85	300	700	6	5.29	2.53	2.76	1.29	0.064	93.6	<0.10	7.1

TABLE 15: ELEMENTAL ANALYSIS OF SPENT SHALES FROM HYDROGEN RETORT OF ONTARIO OGS-83-5 SHALE

Sample	Hydrogen Pressure psi	Final Temp. ^{o}C	Heating Rate ^{o}C/min	Total Carbon (wt%)	Organic Carbon (wt%)	Mineral Carbon (wt%)	Sulphur (wt%)	Nitrogen (wt%)	Ash (wt%)	Moisture (wt%)	Volatiles (wt%)
HR 27	0	500	12	10.80	2.89	7.91	0.50	0.124	67.5	<0.10	32.5
HR 38	100	500	12	11.16	3.32	7.84	0.49	0.126	67.7	<0.10	31.5
HR 76	300	500	12	11.10	2.44	8.66	0.41	0.111	67.3	<0.10	31.3
HR 28	500	500	12	9.44	2.08	7.36	0.46	0.101	67.8	<0.10	31.4
HR 64	800	500	12	10.75	2.49	8.26	0.44	0.089	67.4	0.22	29.4
HR 75	300	400	12	12.93	5.36	7.57	0.46	0.142	65.4	<0.10	33.0
HR 76	300	500	12	11.10	2.44	8.66	0.41	0.111	67.3	<0.10	31.3
HR 78	300	600	12	10.34	2.60	7.74	0.46	0.080	69.8	<0.10	28.7
HR 79	300	700	12	8.83	2.69	6.14	0.14	0.057	78.3	<0.10	19.5
HR 84	300	700	6	7.80	3.01	4.79	0.46	0.047	77.6	<0.10	21.3

TABLE 16: ELEMENTAL ANALYSIS OF OILS FROM HYDROGEN RETORT OF NEW BRUNSWICK 1 SHALE

Sample	Hydrogen Pressure psi	Final Temp. °C	Heating Rate °C/min	Total Carbon (wt%)	Hydrogen (wt%)	Sulphur (wt%)	Nitrogen (wt%)	Oxygen (wt%)
HR 45	0	500	12	85.16	11.70	0.54	1.15	1.45
HR 24	100	500	12	82.95	11.24	0.43	1.10	4.28
HR 19	300	500	12	86.63	11.76	0.37	1.21	0.03
HR 37	500	500	12	85.57	10.84	0.33	1.24	2.02
HR 57	100	400	12	84.32	12.41	0.44	0.68	2.15
HR 24	100	500	12	82.95	11.24	0.43	1.10	4.28
HR 58	100	600	12	86.10	11.89	0.46	1.16	0.39
HR 59	100	700	12	85.13	12.74	0.55	1.18	0.40
HR 68	100	700	6	84.62	11.50	0.43	1.34	2.11

TABLE 17: ELEMENTAL ANALYSIS OF OILS FROM HYDROGEN RETORT OF NEW BRUNSWICK 2 SHALE

Sample	Hydrogen Pressure psi	Final Temp. ^{o}C	Heating Rate ^{o}C/min	Total Carbon (wt%)	Hydrogen (wt%)	Sulphur (wt%)	Nitrogen (wt%)	Oxygen (wt%)
HR 15	0	500	12	86.55	11.56	0.32	1.47	0.10
HR 43	100	500	12	85.15	12.80	0.33	1.32	0.40
HR 35	300	500	12	85.68	11.07	0.31	1.75	1.19
HR 36	500	500	12	85.17	11.23	0.28	1.93	1.39
HR 66	100	400	12	83.38	11.53	0.38	1.02	3.69
HR 43	100	500	12	85.15	12.80	0.33	1.32	0.40
HR 67	100	600	12	82.71	10.98	0.32	1.44	4.55
HR 62	100	700	12	85.55	11.45	0.33	1.52	1.15
HR 70	100	700	6	85.17	11.00	1.81	0.41	1.61

TABLE 18: ELEMENTAL ANALYSIS OF OILS FROM HYDROGEN RETORT OF NEWFOUNDLAND 189-10 SHALE

Sample	Hydrogen Pressure psi	Final Temp. °C	Heating Rate °C/min	Total Carbon (wt%)	Hydrogen (wt%)	Sulphur (wt%)	Nitrogen (wt%)	Oxygen (wt%)
HR 32	0	500	12	84.37	11.05	0.34	1.28	2.96
HR 33	100	500	12	85.82	11.62	0.38	1.28	0.90
HR 81	300	500	12	84.79	11.18	0.34	1.22	2.47
HR 34	500	500	12	85.73	11.88	0.39	1.10	0.90
HR 63	800	500	12	86.44	11.21	0.28	1.26	0.81
HR 80	300	400	12	86.51	10.99	0.44	1.05	1.01
HR 81	300	500	12	84.79	11.18	0.34	1.22	2.47
HR 82	300	500	12	85.37	11.67	0.32	1.15	1.49
HR 83	300	600	12	84.27	11.19	0.38	1.25	2.91
HR 86	300	700	6	84.22	10.87	0.33	1.23	3.35

TABLE 19: ELEMENTAL ANALYSIS OF OILS FROM HYDROGEN RETORT OF ONTARIO OGS-83-3 SHALE

Sample	Hydrogen Pressure psi	Final Temp. °C	Heating Rate °C/min	Total Carbon (wt%)	Hydrogen (wt%)	Sulphur (wt%)	Nitrogen (wt%)	Oxygen (wt%)
HR 29	0	500	12		(Sample Lost in Shipping)			
HR 30	100	500	12	76.00	10.13	0.72	0.99	12.16
HR 77	300	500	12	80.31	10.37	0.65	0.95	7.72
HR 31	500	500	12	86.58	8.02	0.91	1.69	2.80
HP 65	800	500	12	87.47	10.30	0.49	1.23	0.51
HR 71	300	400	12		(Sample Lost in Shipping)			
HR 77	300	500	12	80.31	10.37	0.65	0.95	7.72
HR 73	300	600	12	87.04	11.41	0.61	0.81	0.13
HR 74	300	700	12	82.03	10.51	0.55	0.97	5.94
HR 85	300	700	6	85.51	11.34	0.57	0.89	1.69

TABLE 20: ELEMENTAL ANALYSIS OF OILS FROM HYDROGEN RETORT OF ONTARIO OGS-83-5 SHALE

Sample	Hydrogen Pressure psi	Final Temp. °C	Heating Rate °C/min	Total Carbon (wt%)	Hydrogen (wt%)	Sulphur (wt%)	Nitrogen (wt%)	Oxygen (wt%)
HR 27	0	500	12	78.72	10.88	0.66	0.88	8.86
HR 38	100	500	12	85.67	10.36	1.18	1.19	1.60
HR 76	300	500	12	83.77	10.54	1.40	1.00	3.29
HR 28	500	500	12	86.40	10.24	1.45	1.31	0.60
HR 64	800	500	12	83.82	11.82	1.13	0.73	2.50
HR 75	300	400	12	83.08	10.17	1.39	1.37	3.99
HR 76	300	500	12	83.77	10.54	1.40	1.00	3.29
HR 78	300	600	12	81.01	9.18	1.41	1.43	6.97
HR 79	300	700	12	76.23	8.90	1.31	1.59	11.97
HR 84	300	700	6	81.27	9.76	1.19	1.35	6.43

Figure 4: Organic Carbon vs. Fischer Assay Oil Yield

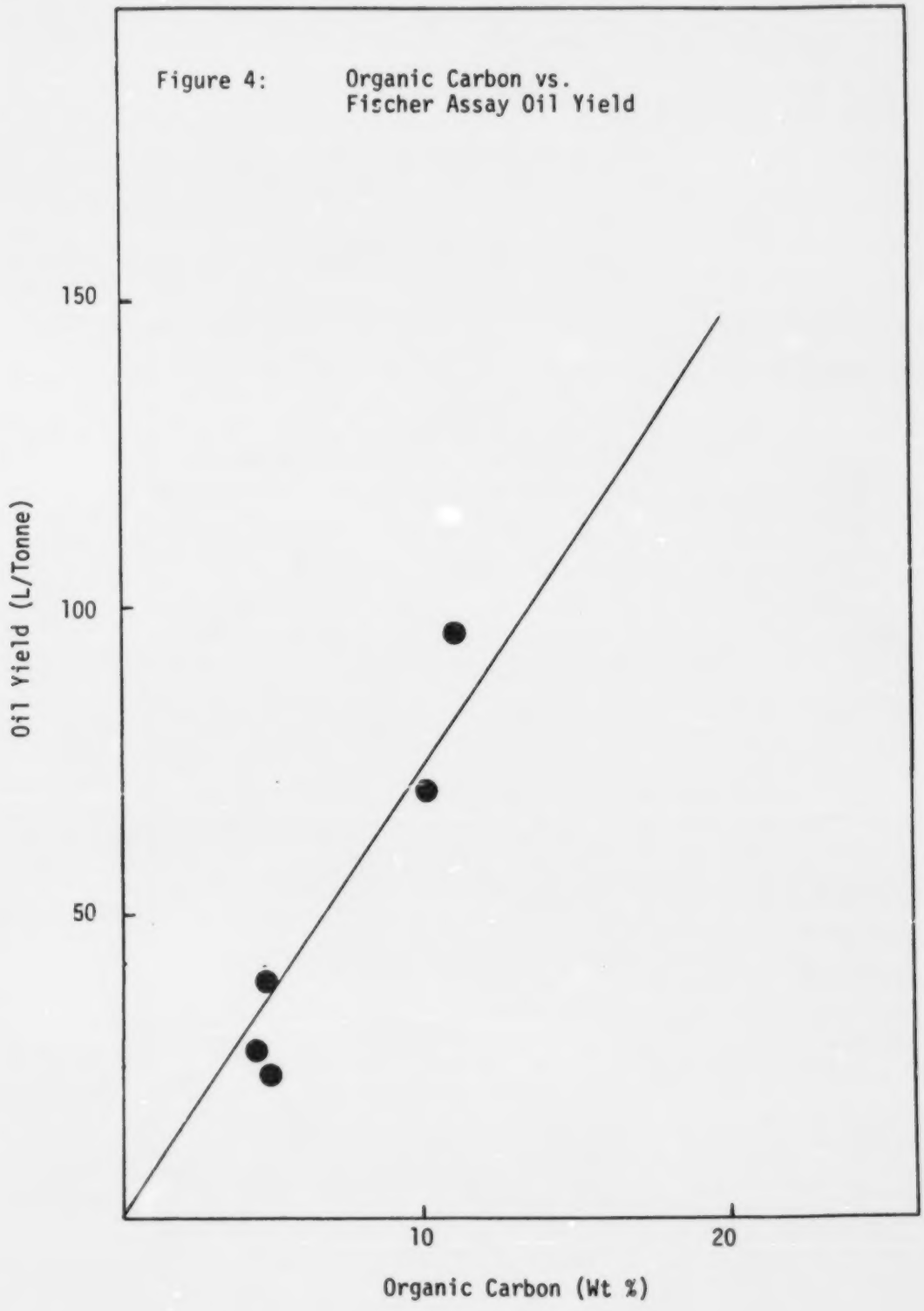


Figure 5: Organic Carbon vs. Fischer Assay and Hydrogen Retort Oil Yields

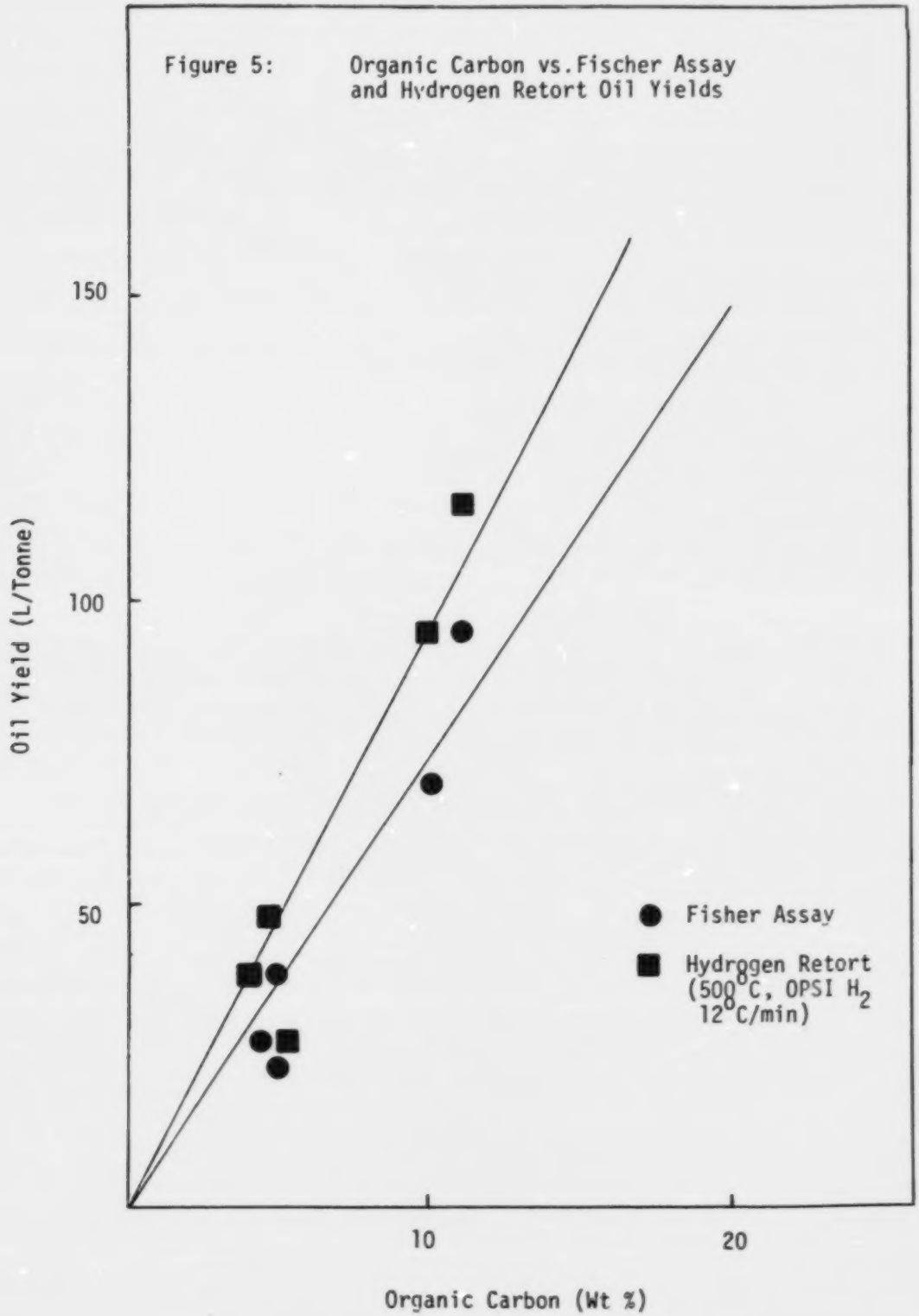


Figure 6: H_2 Pressure vs Yields for New Brunswick -1 Shale at 500°C Final Temperature

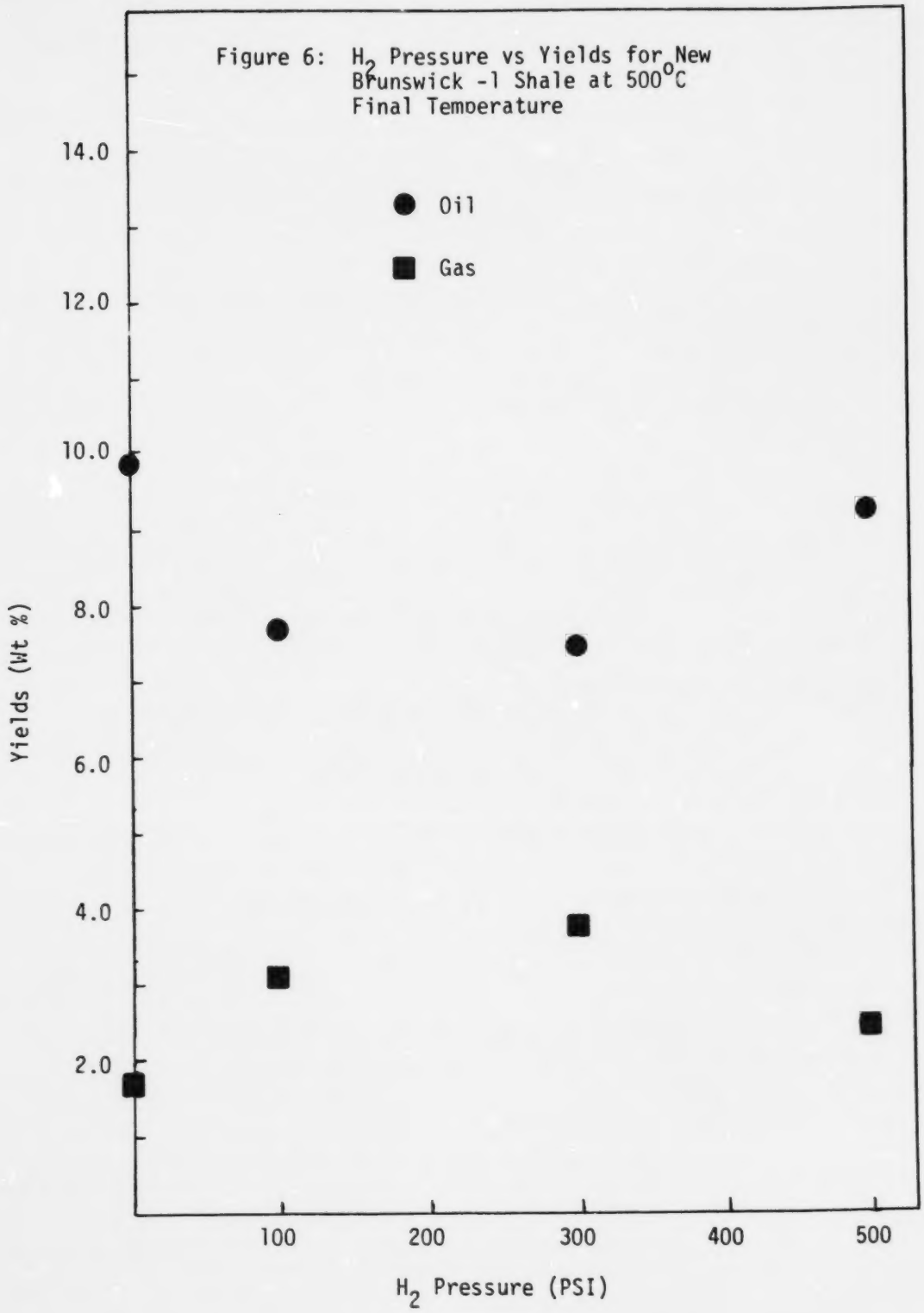


Figure 7: H_2 Pressure vs Yields for New Brunswick -2 Shale at 500°C Final Temperature

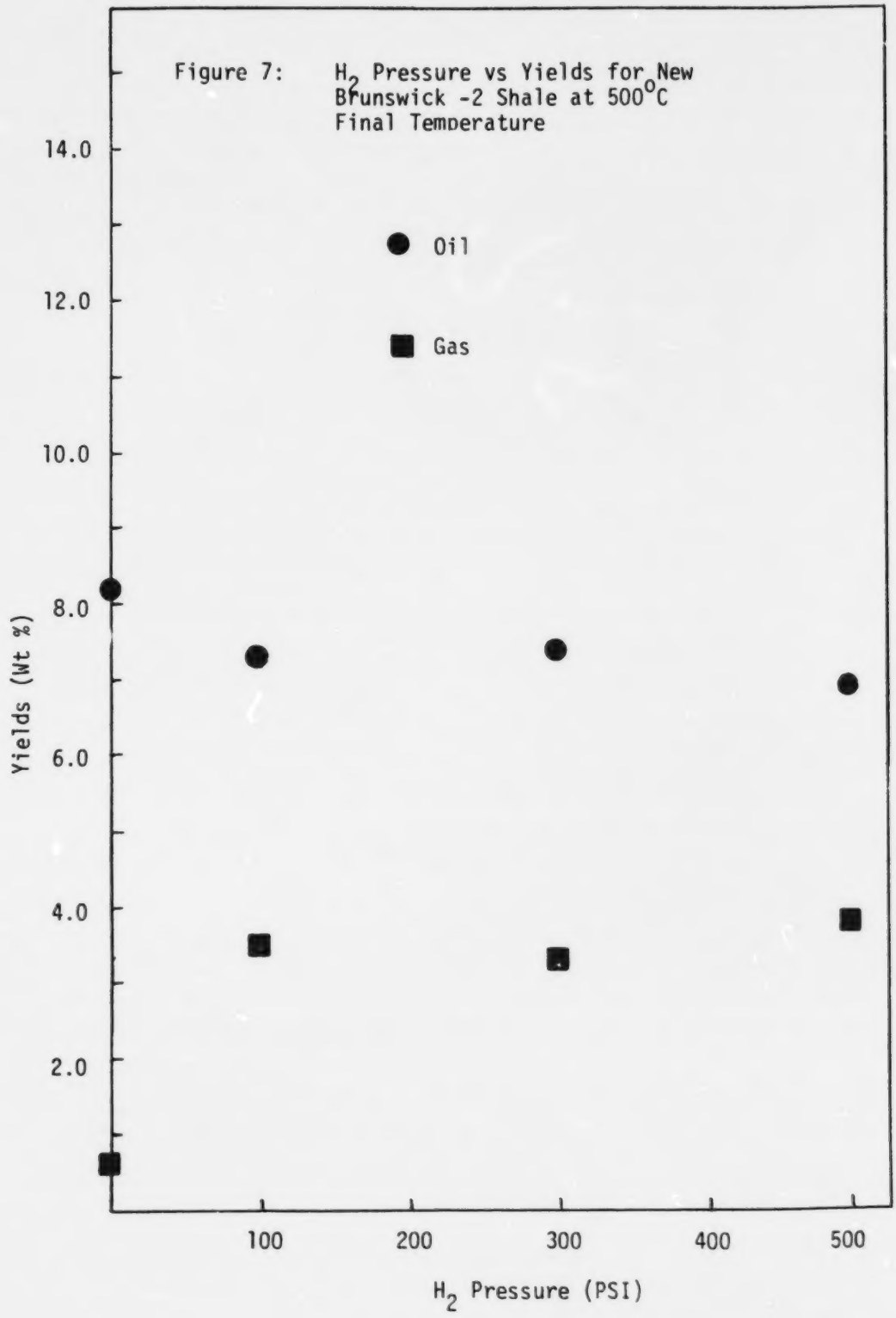


Figure 8: H_2 Pressure vs Yields for Newfoundland 189-10 Shale at 500°C Final Temperature

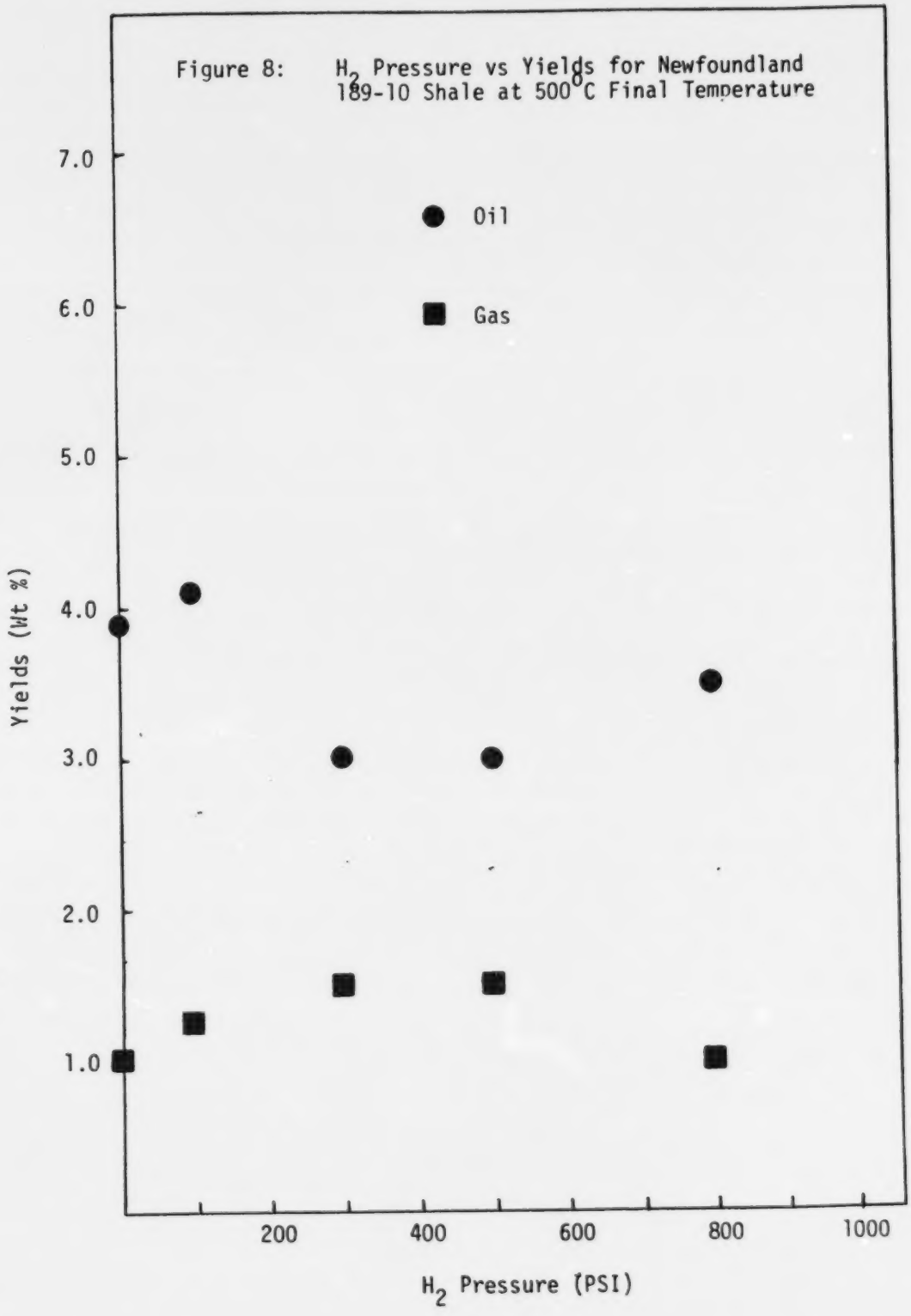


Figure 9: H_2 Pressure vs Yields for Ontario OGS-83-3 Shale at 500° C Final Temperature

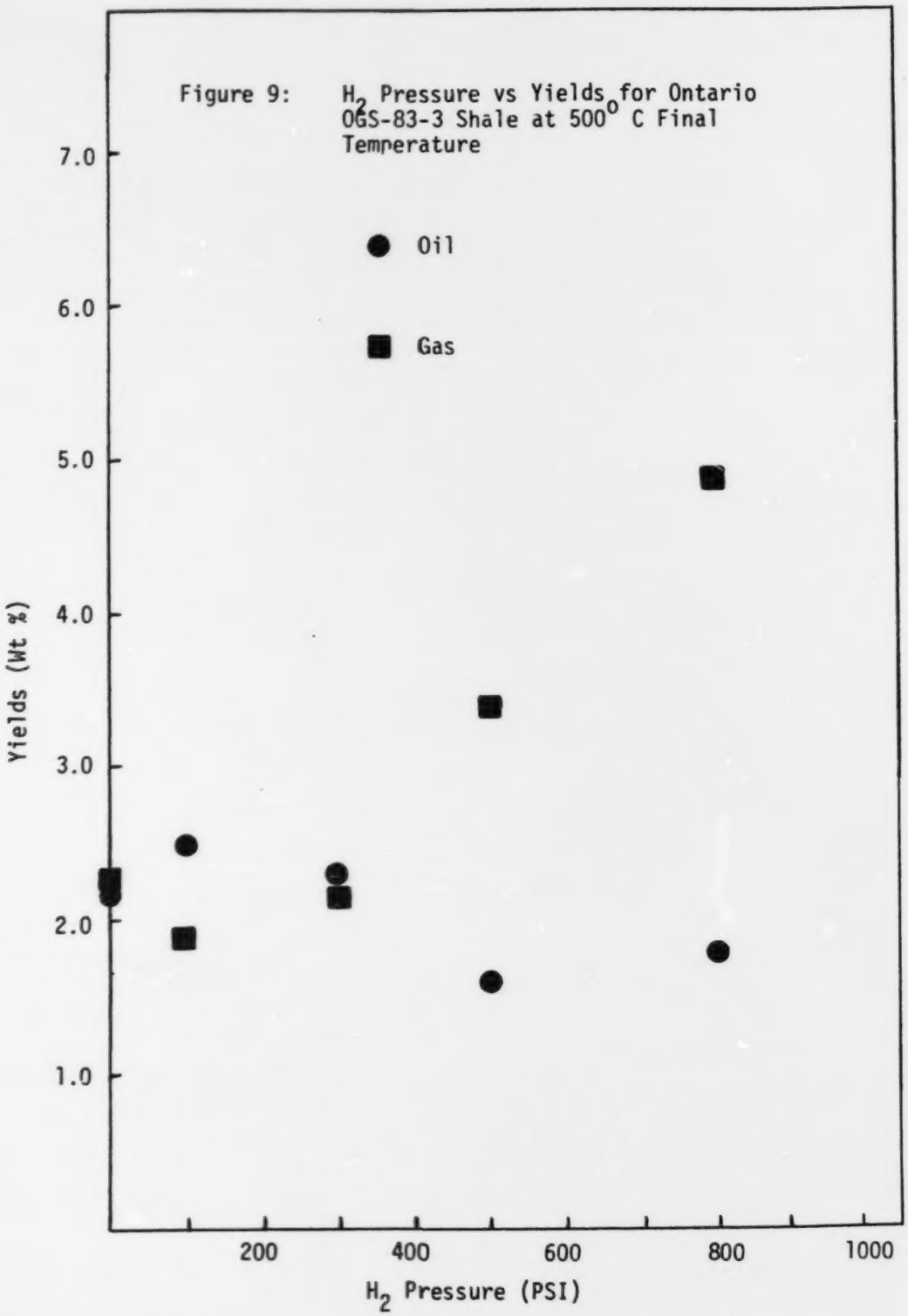


Figure 10: H_2 Pressure vs Yields for Ontario OGS-83-5 Shale at 500° C Final Temperature

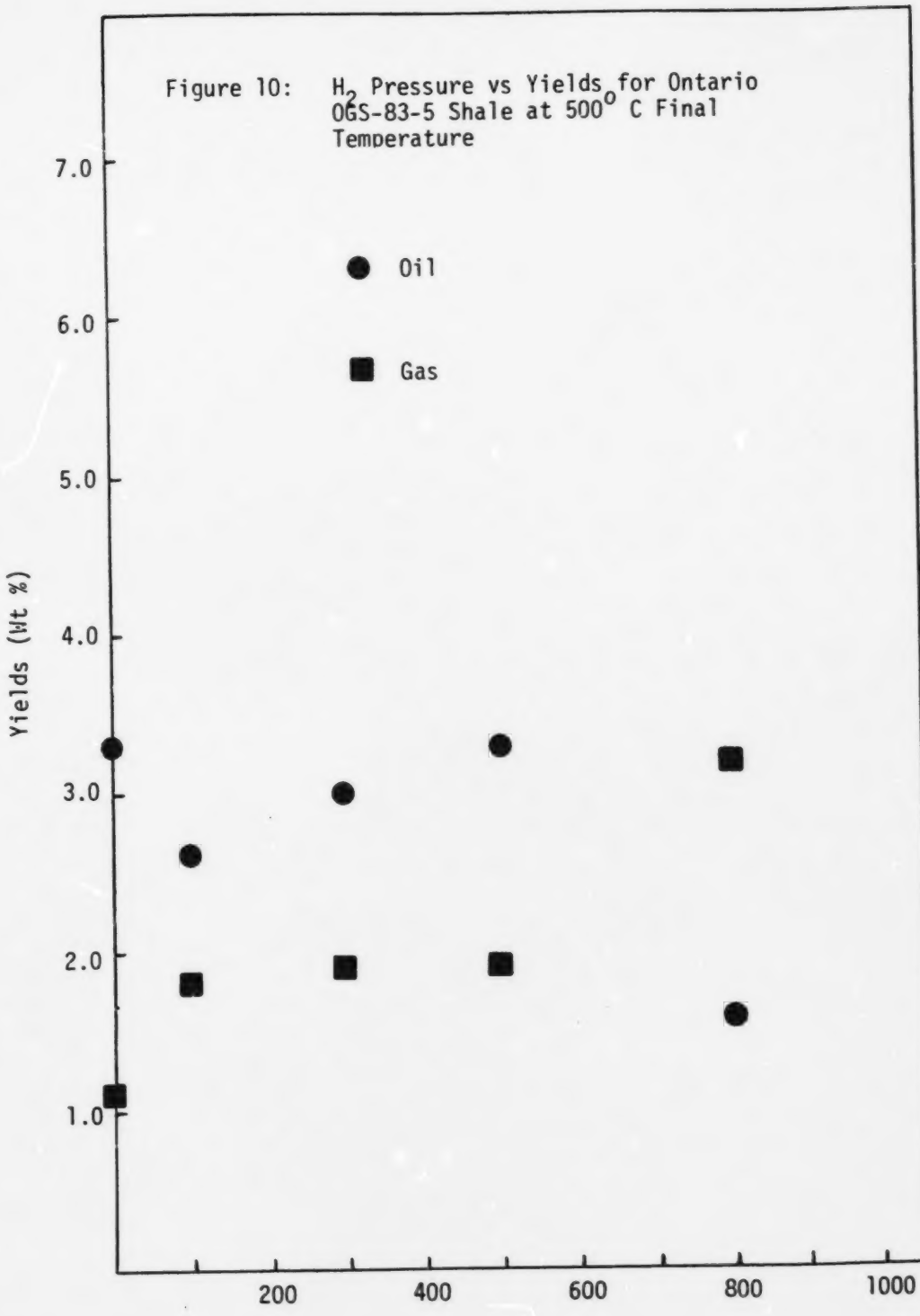


Figure 11: Final Temperature vs Yields for New Brunswick -1 Shale at 100 PSI H_2

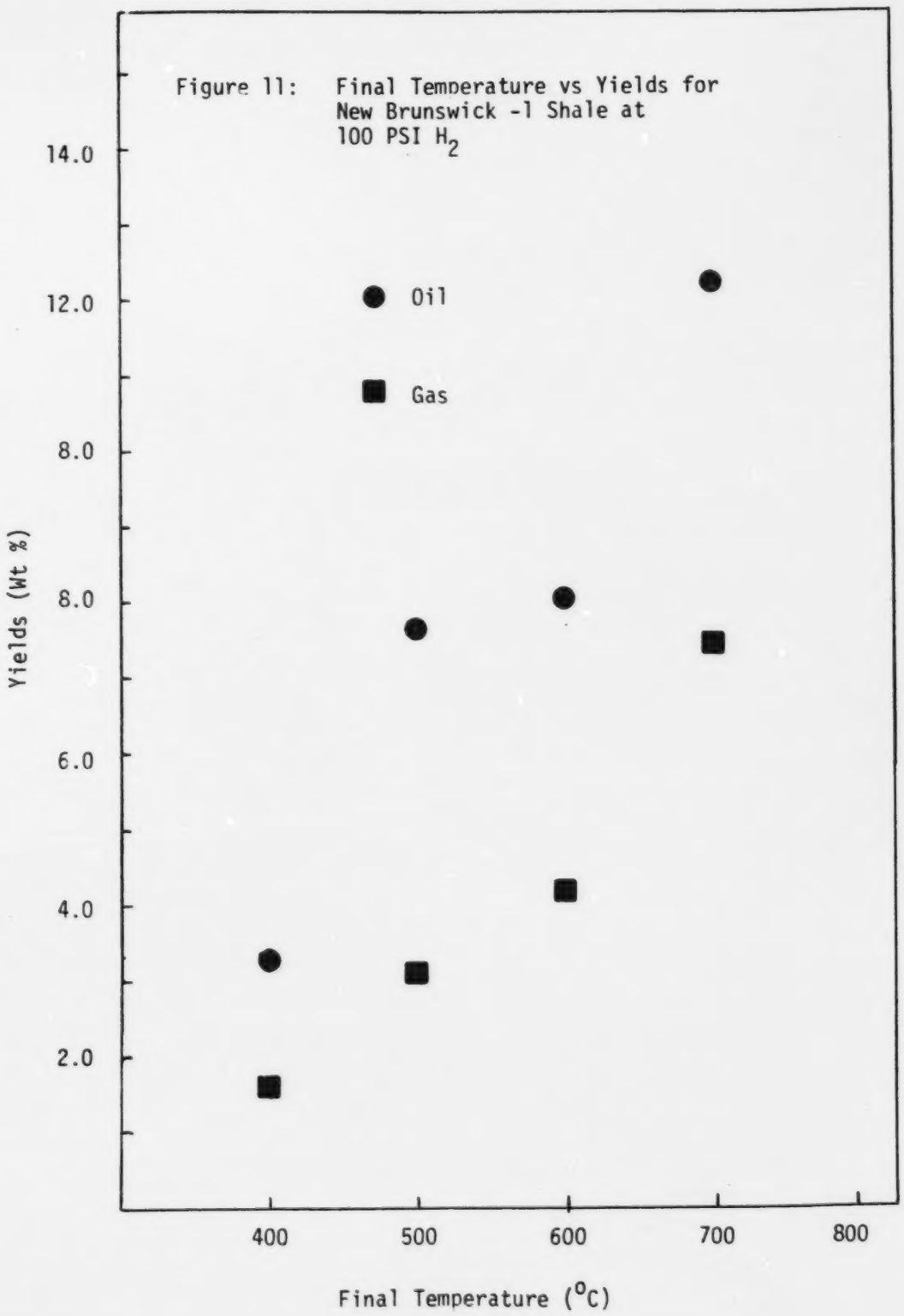


Figure 12: Final Temperature vs Yields for New Brunswick -2 Shale at 100 PSI H_2

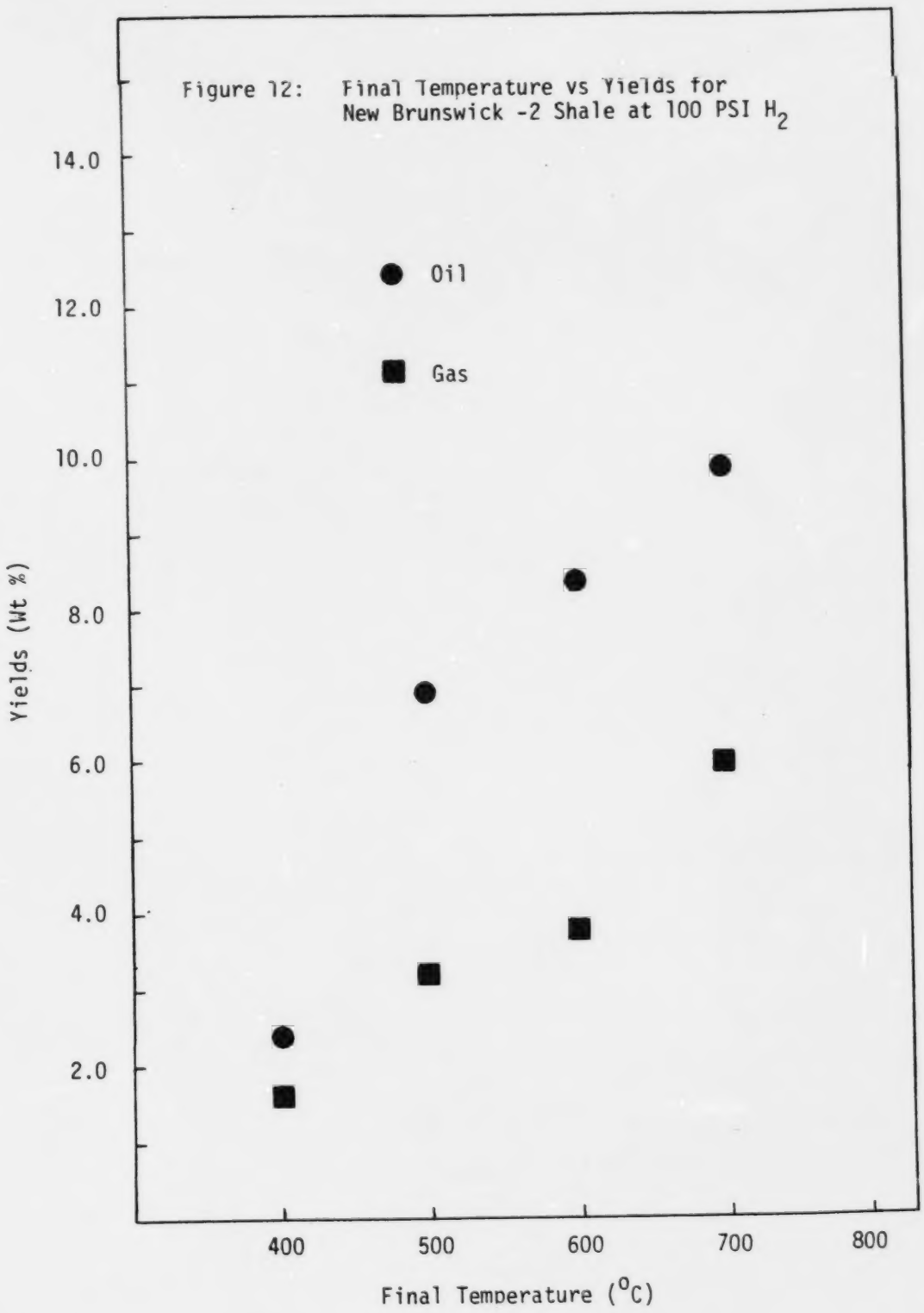


Figure 13: Final Temperature vs Yields for Newfoundland 189-10 Shale at 300 PSI H_2

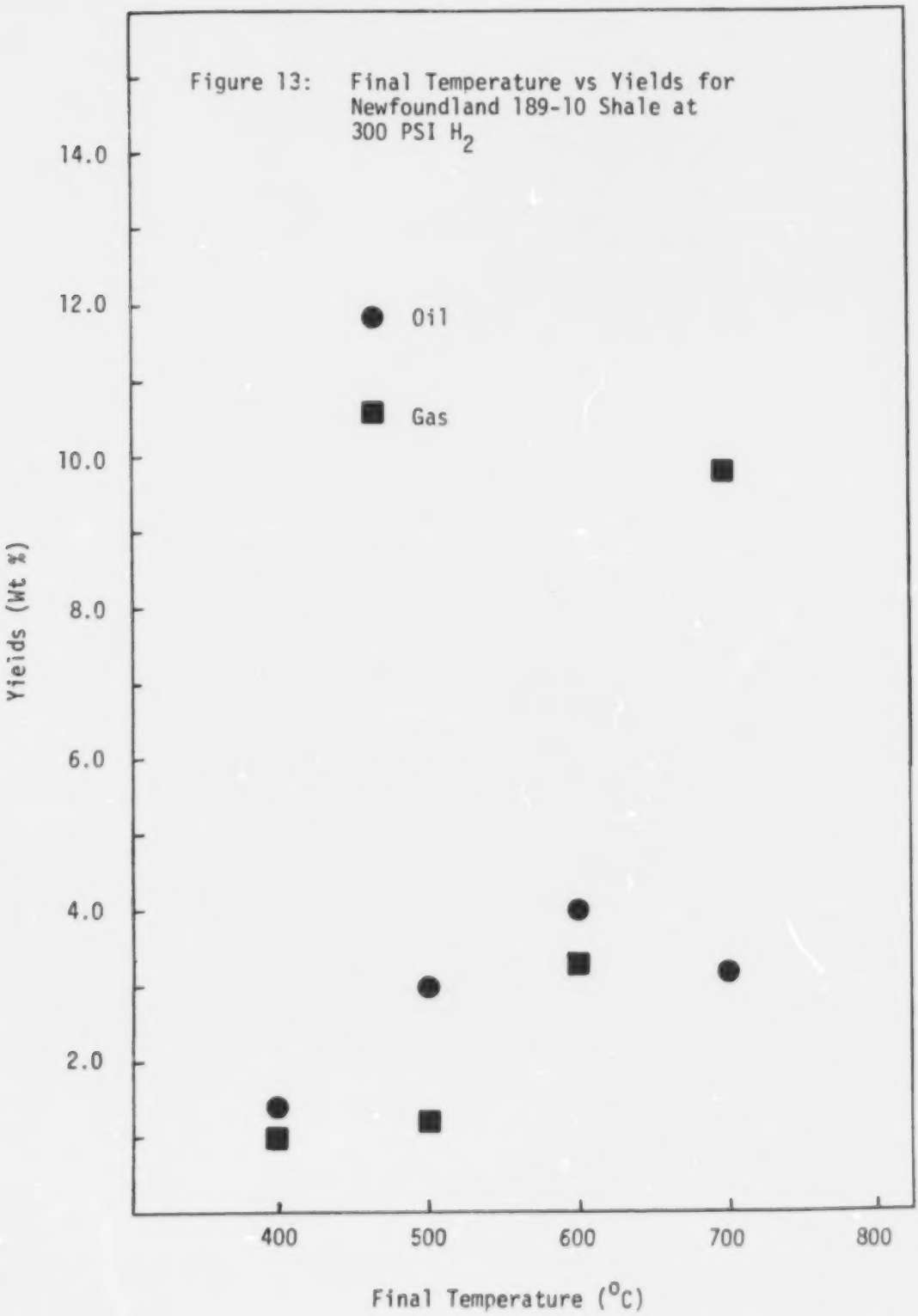


Figure 14: Final Temperature vs Yields for Ontario OGS-83-3 Shale at 300 PSI H_2

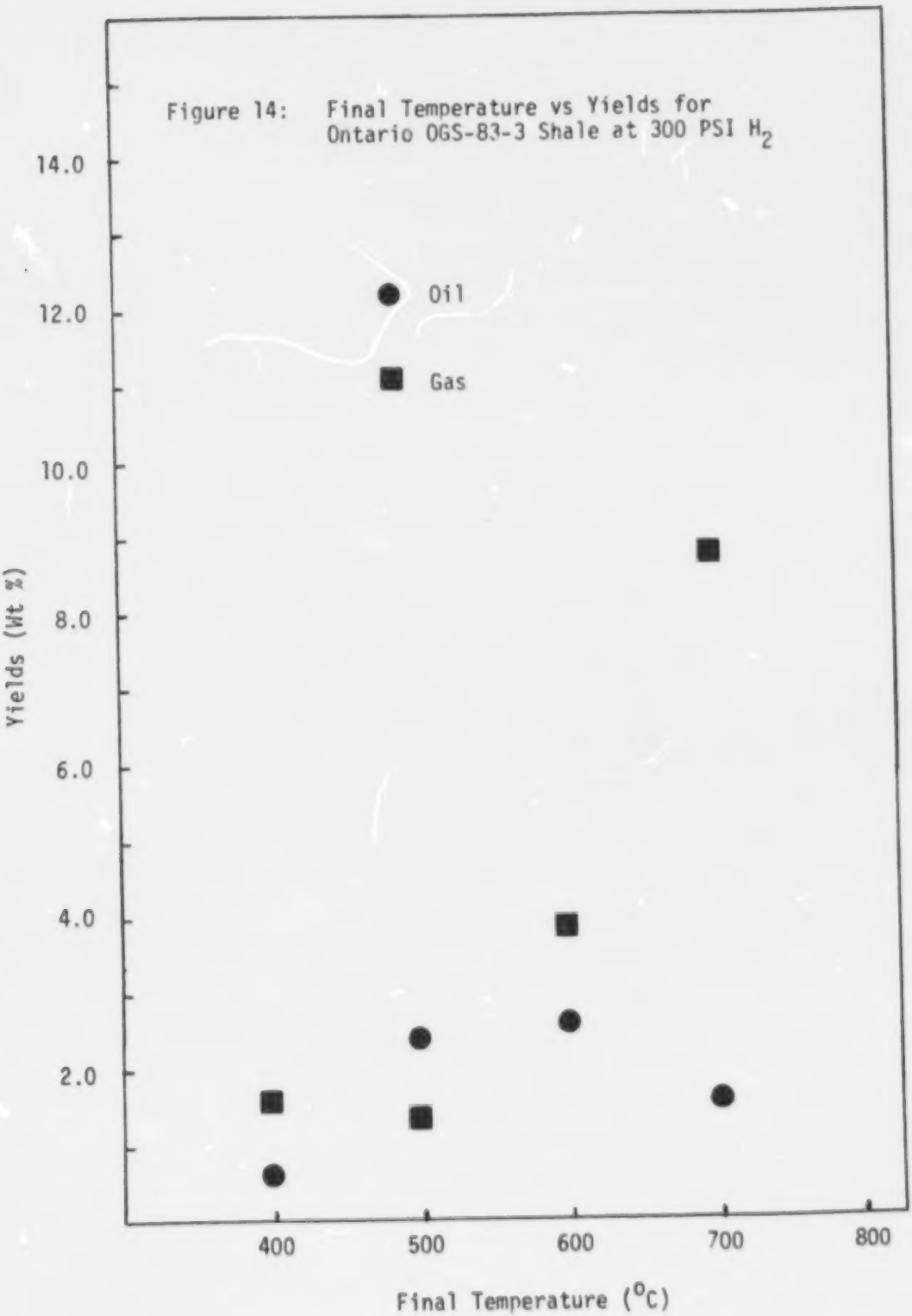


Figure 15: Final Temperature vs Yields for Ontario OGS-83-5 Shale at 300 PSI H_2

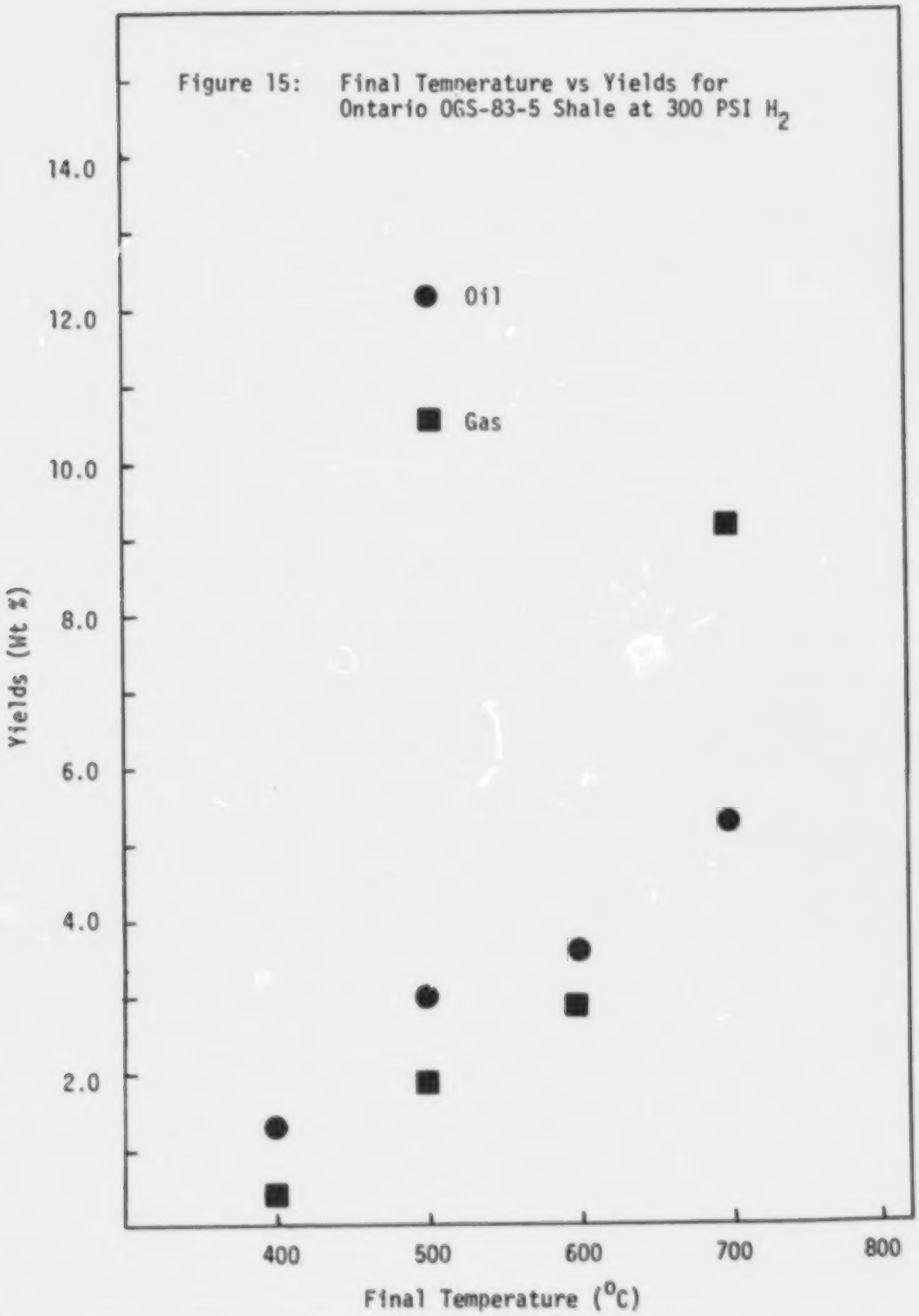


Figure 16: H_2 Pressure vs Organic Carbon in New Brunswick -1 Spent Shale at 500°C Final Temperature

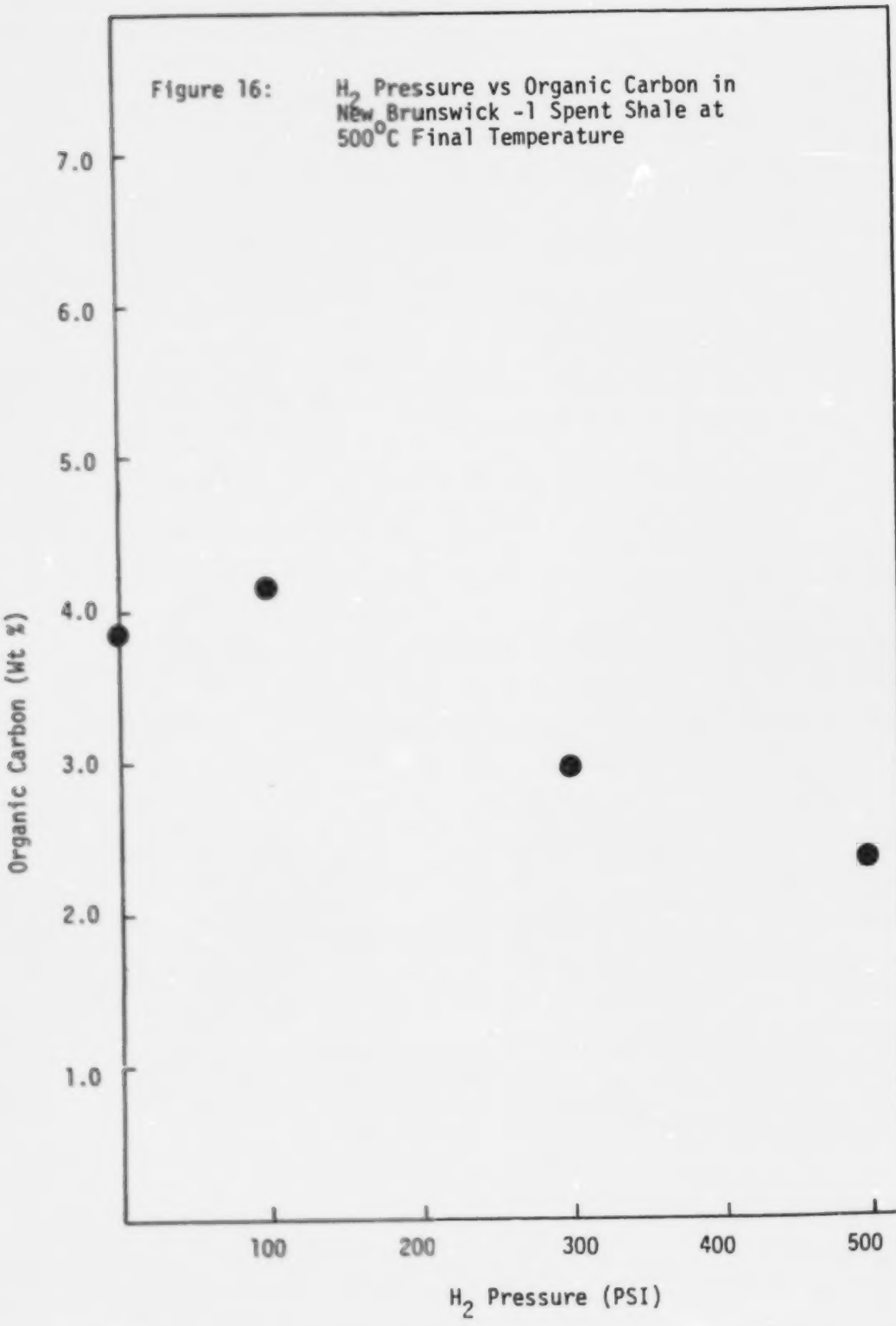


Figure 17: H_2 Pressure vs Organic Carbon in New Brunswick -2 Spent Shale at 500°C Final Temperature

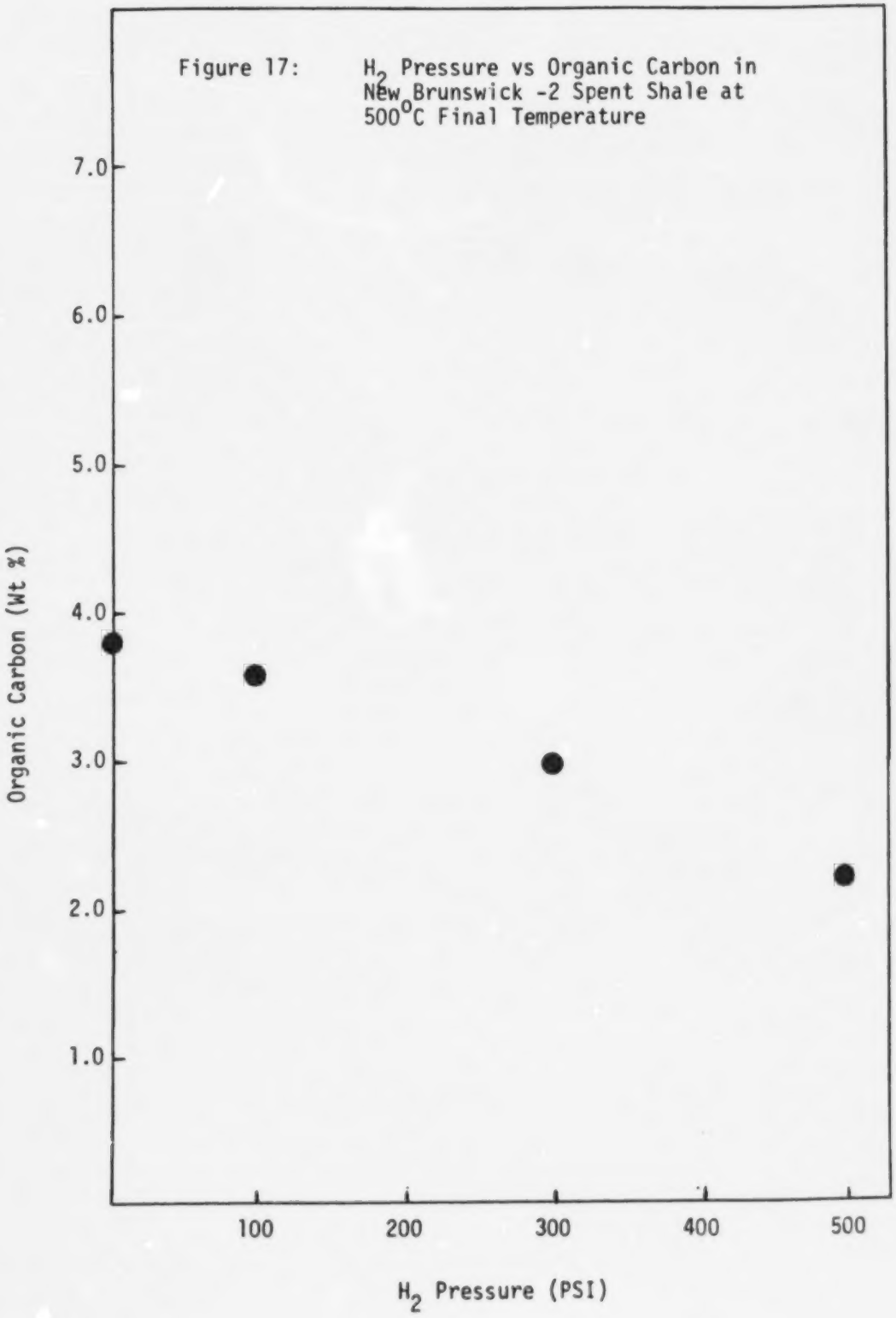


Figure 18: H_2 Pressure vs Organic Carbon in Newfoundland 189-10 Spent Shale at 500°C Final Temperature

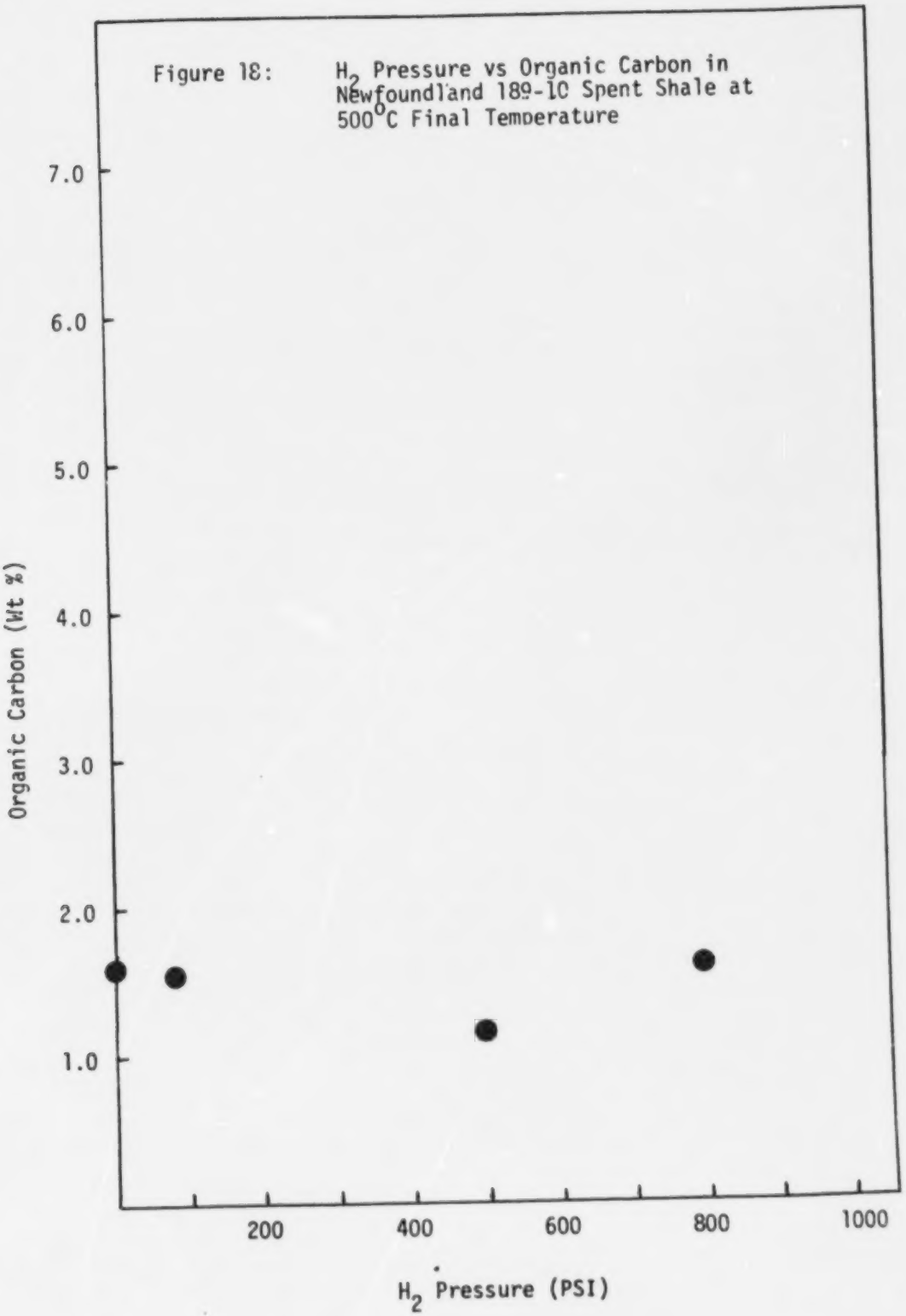


Figure 19: H_2 Pressure vs Organic Carbon in Ontario OGS-83-3 Spent Shale at 500°C Final Temperature

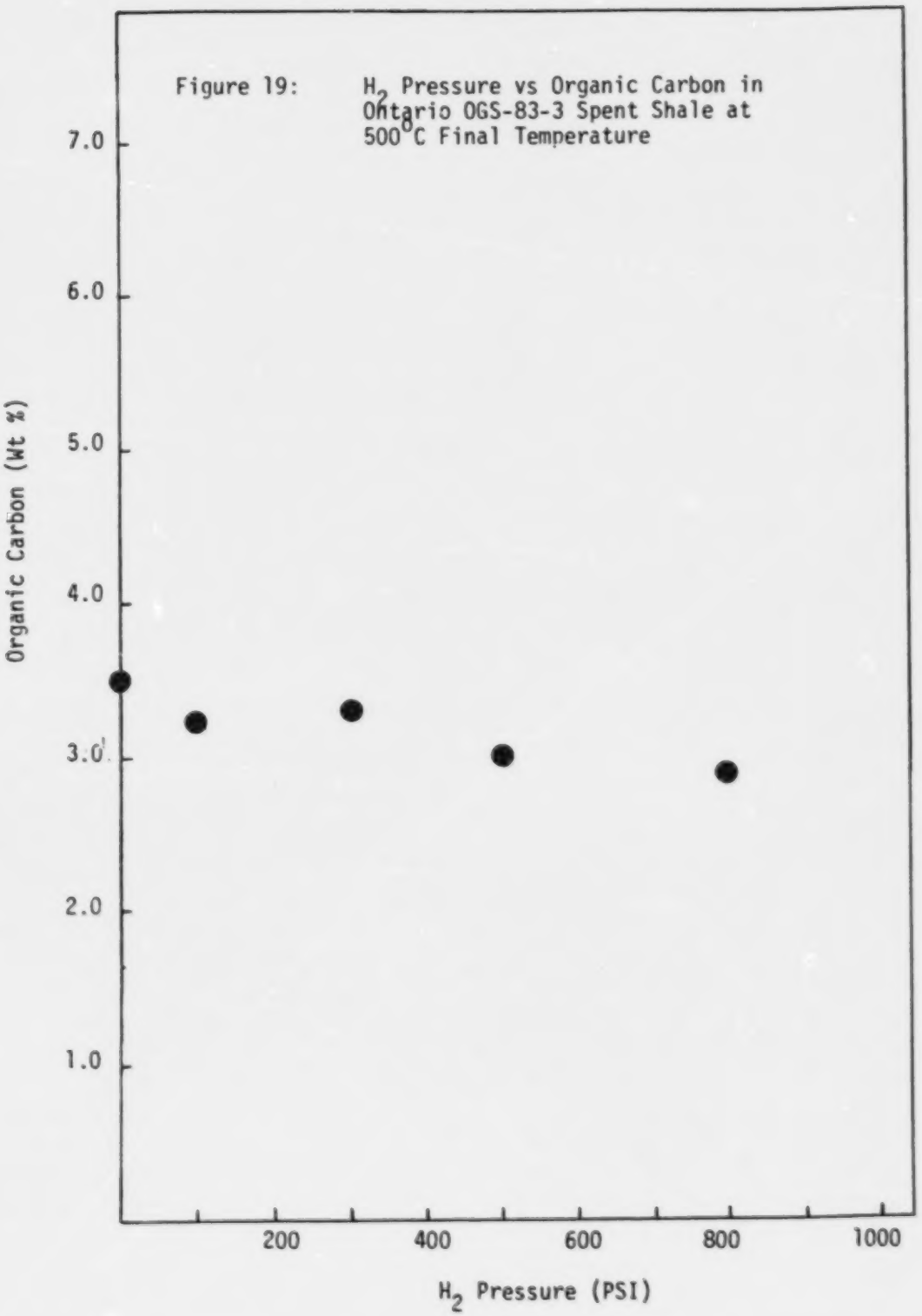


Figure 20: H_2 Pressure vs Organic Carbon in Ontario OGS 83-5 Spent Shale at 500°C Final Temperature

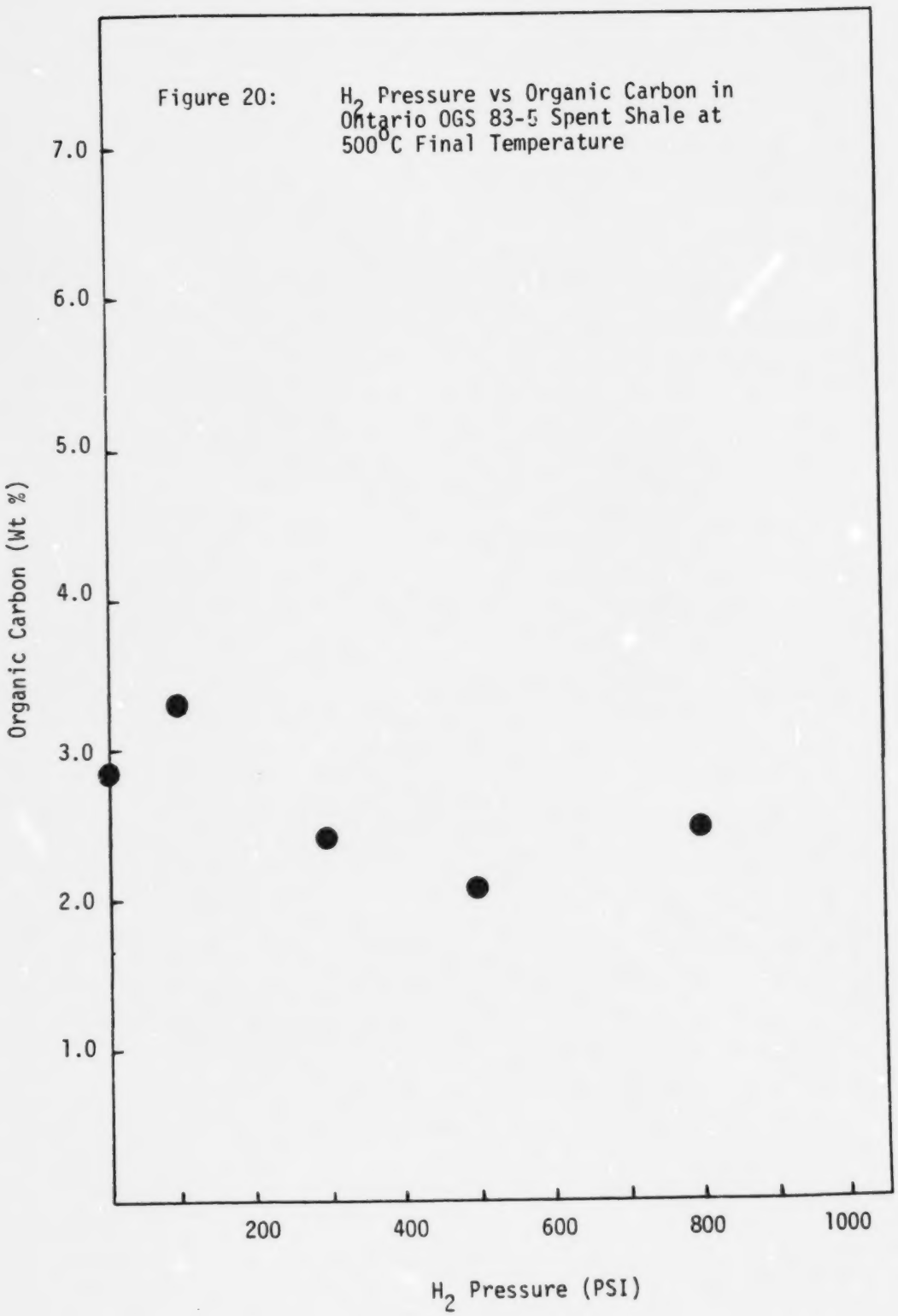


Figure 21: Final Temperature vs Organic Carbon in New Brunswick -1 Spent Shale at 100 PSI H_2

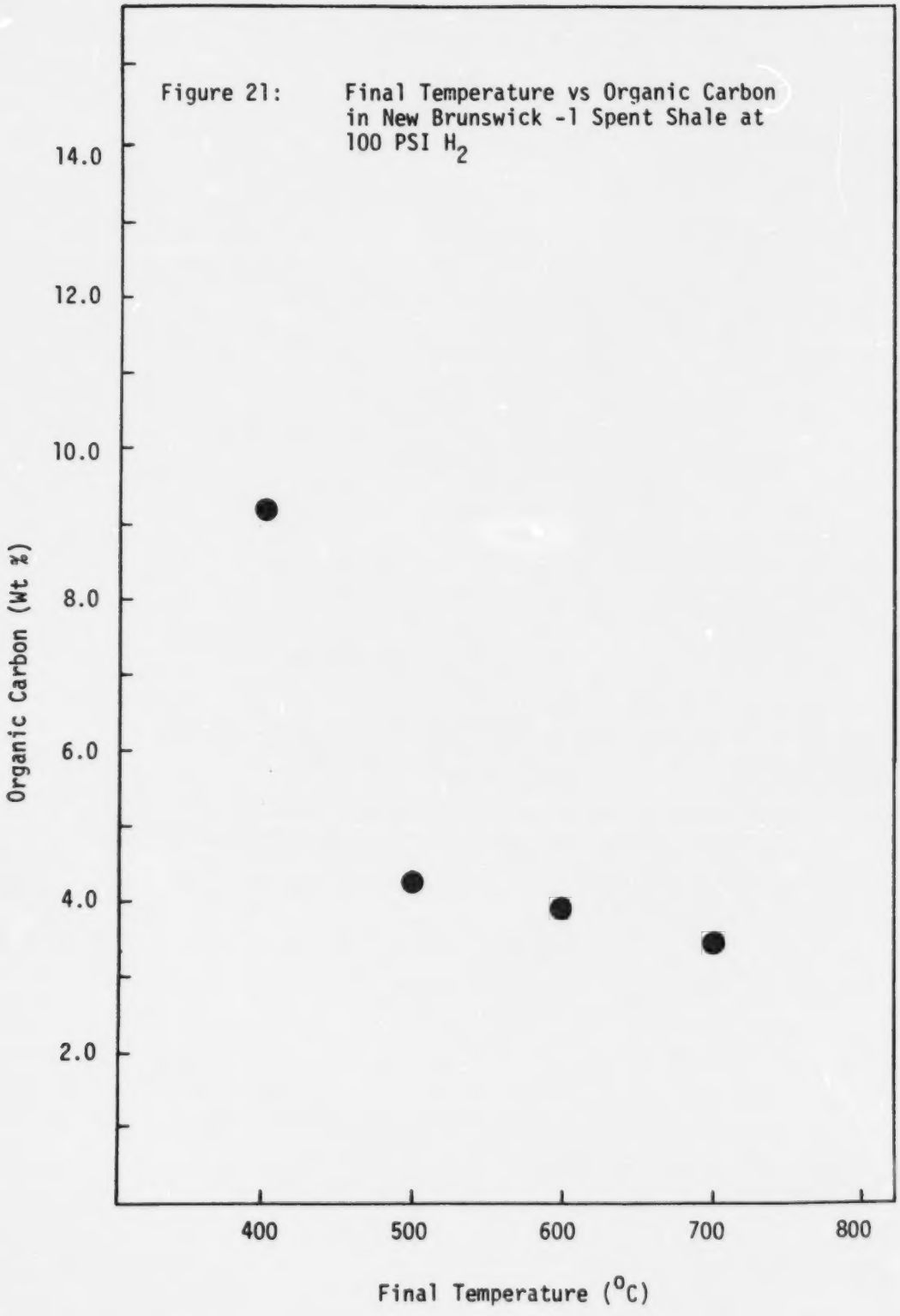


Figure 22: Final Temperature vs Organic Carbon in New Brunswick -2 Spent Shale at 100 PSI H_2

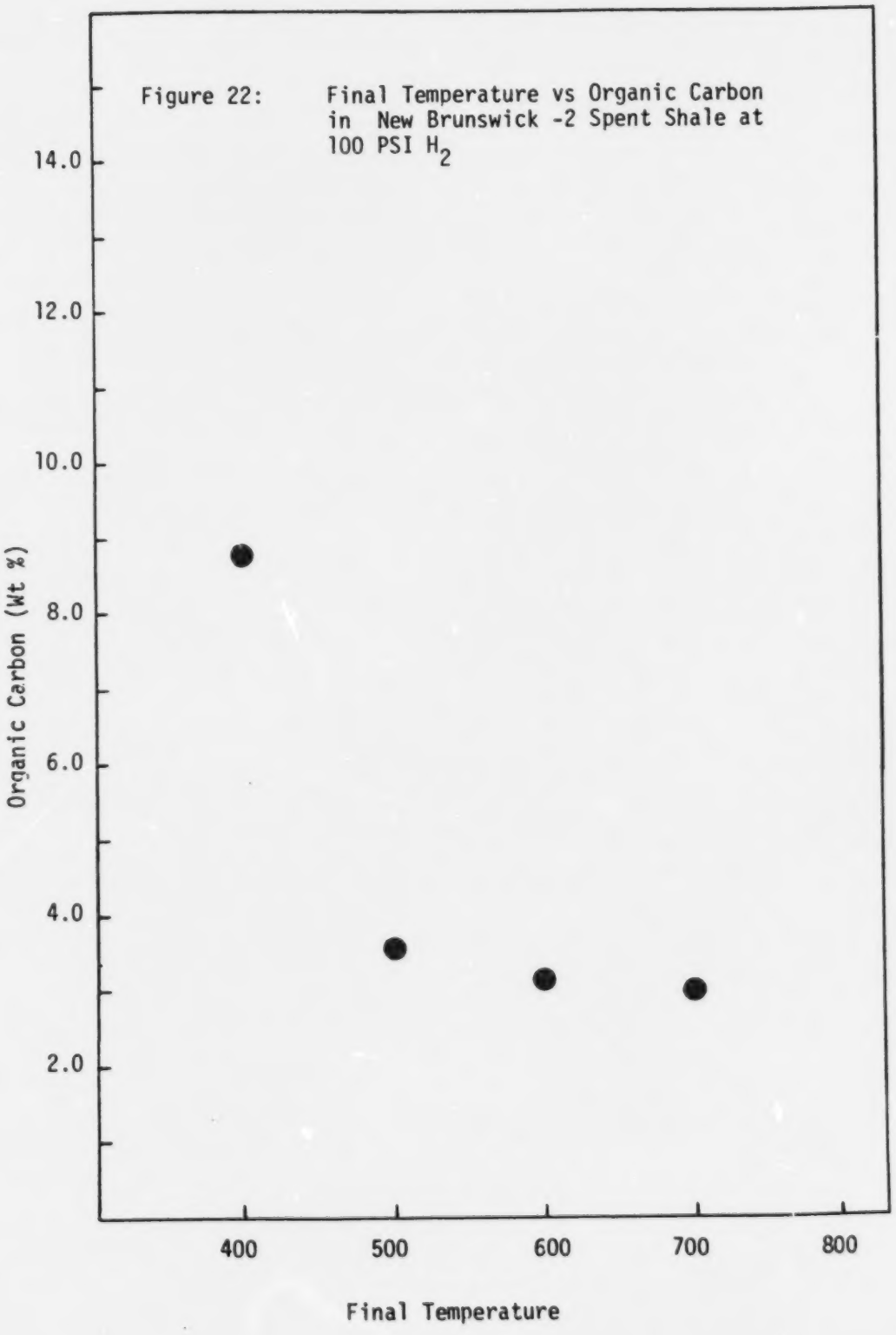


Figure 23: Final Temperature vs Organic Carbon in Newfoundland 189-10 Spent Shale at 300 PSI H_2

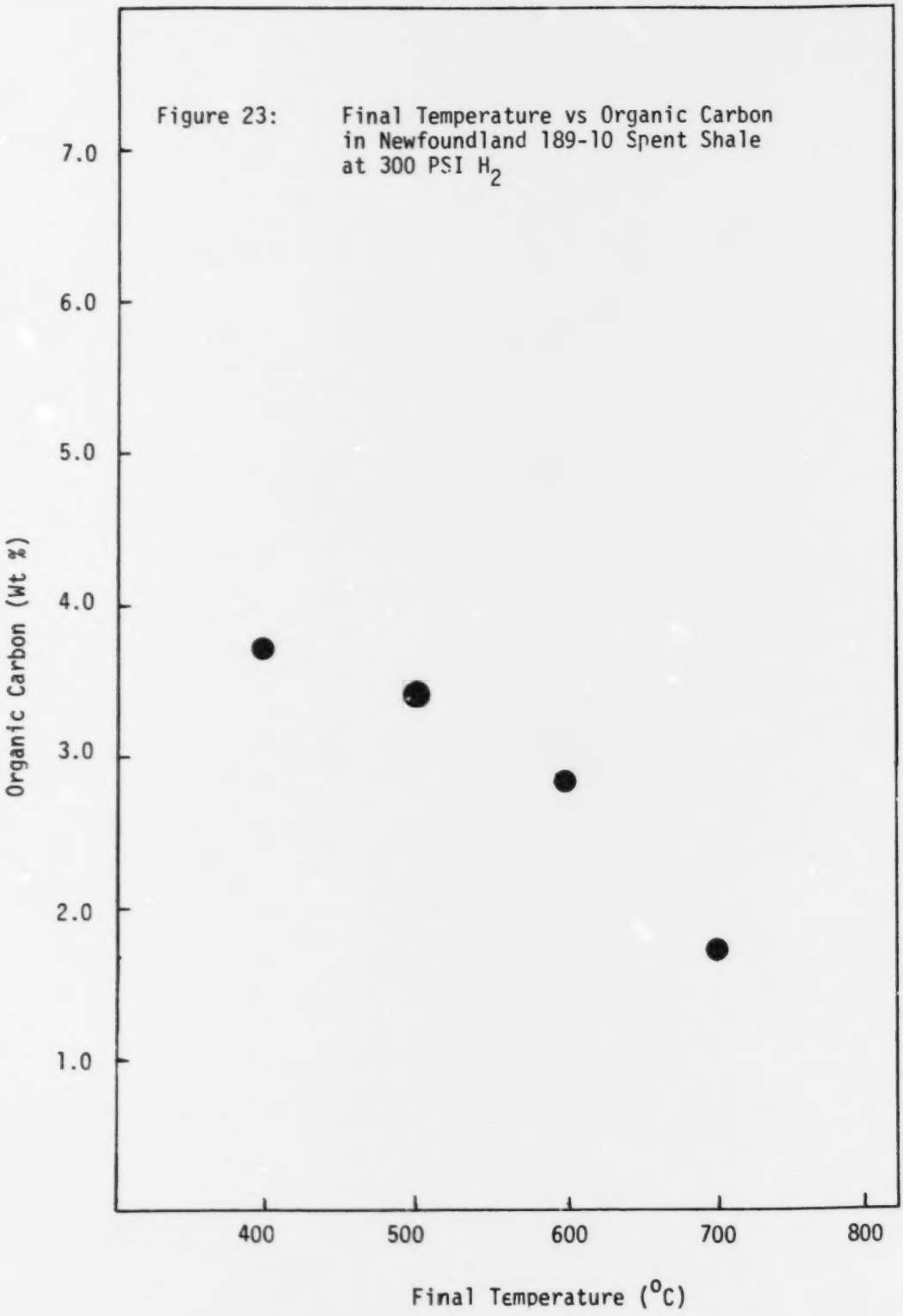


Figure 24: Final Temperature vs Organic Carbon in Ontario OGS 83-3 Spent Shale at 300 PSI H_2

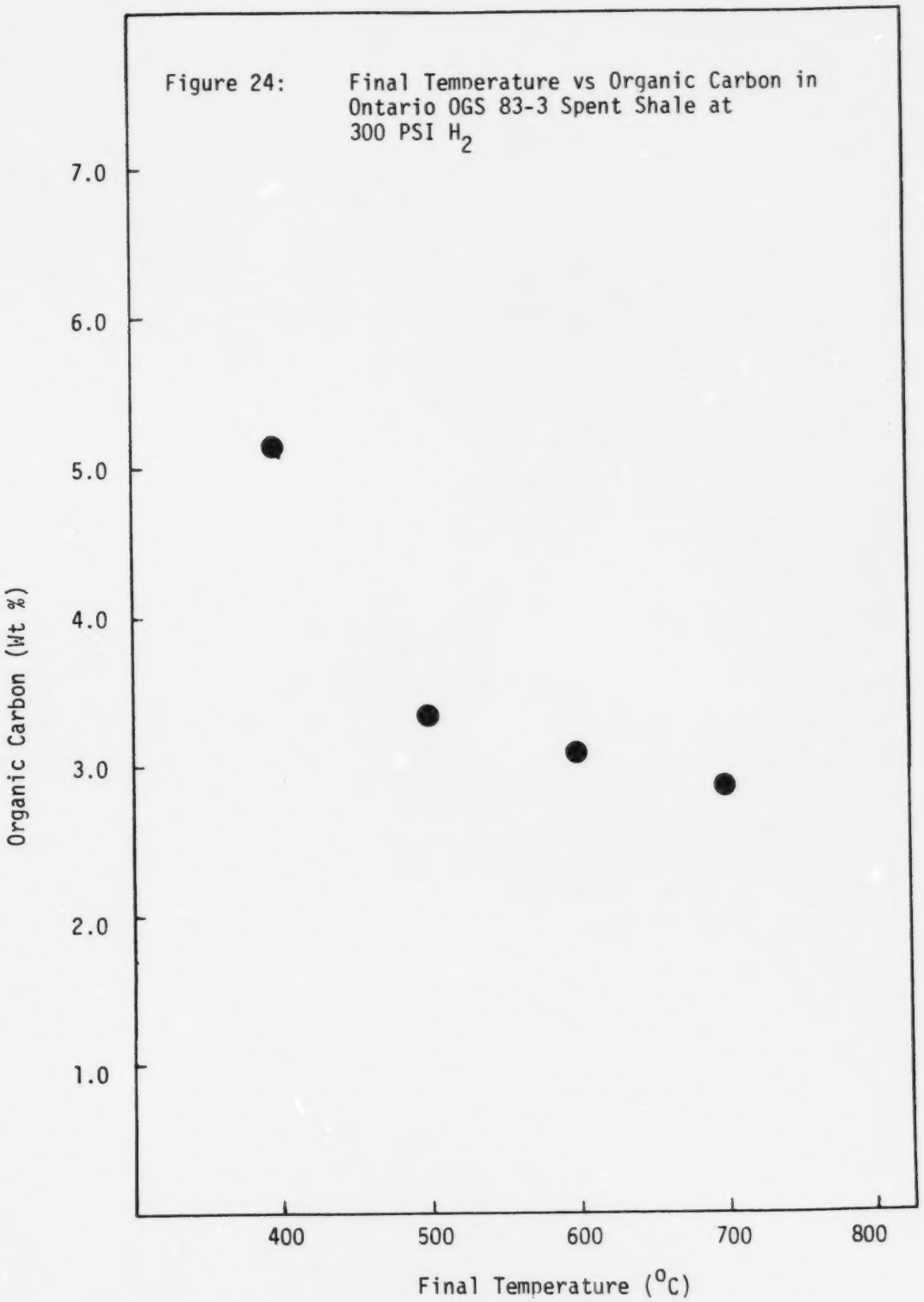


Figure 25: Final Temperature vs Organic Carbon in Ontario OGS-83-5 Spent Shale at 300 PSI H_2

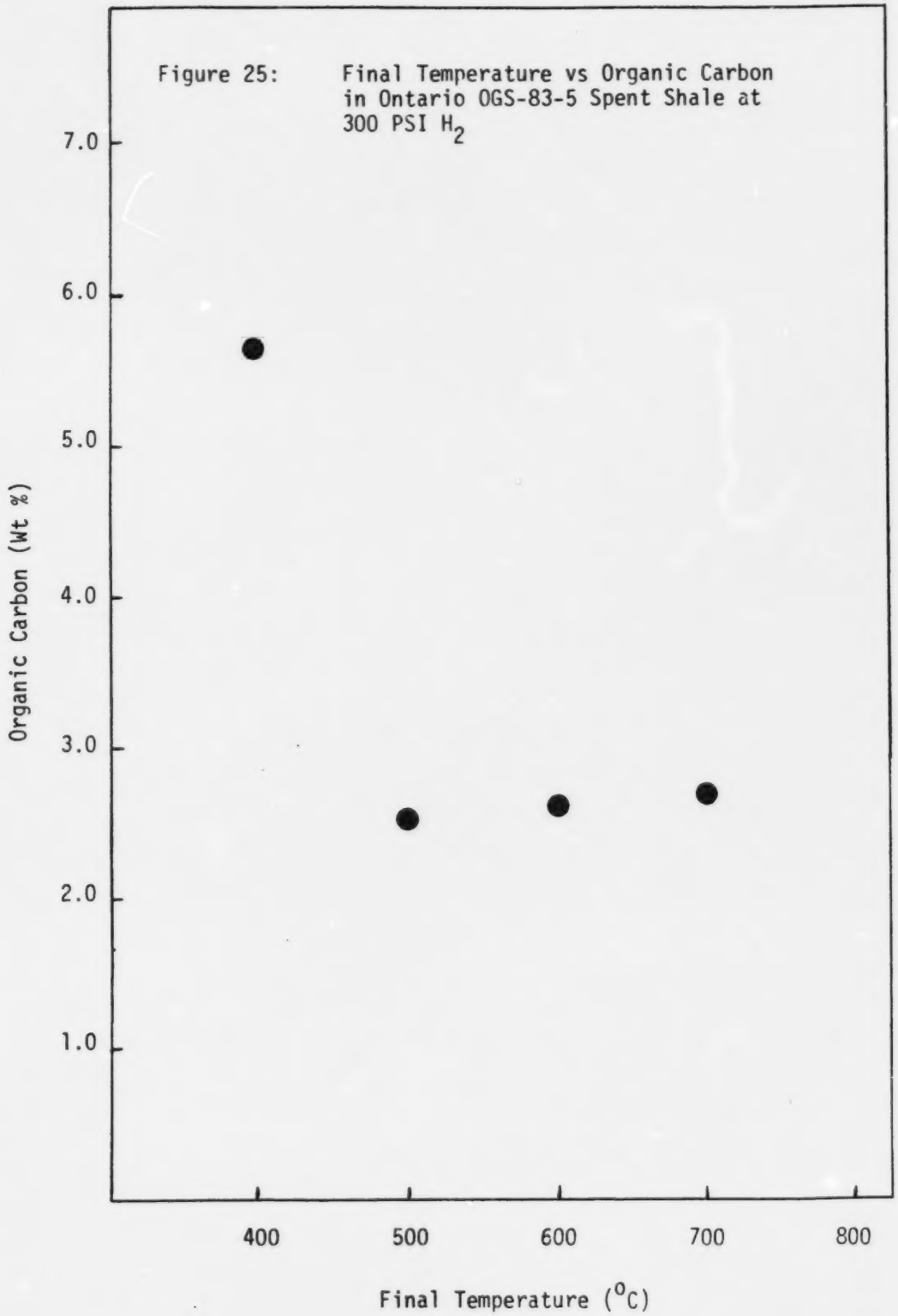


Figure 26: Final Temperature vs Mineral Carbon for New Brunswick -1 Spent Shale at 100 PSI H_2

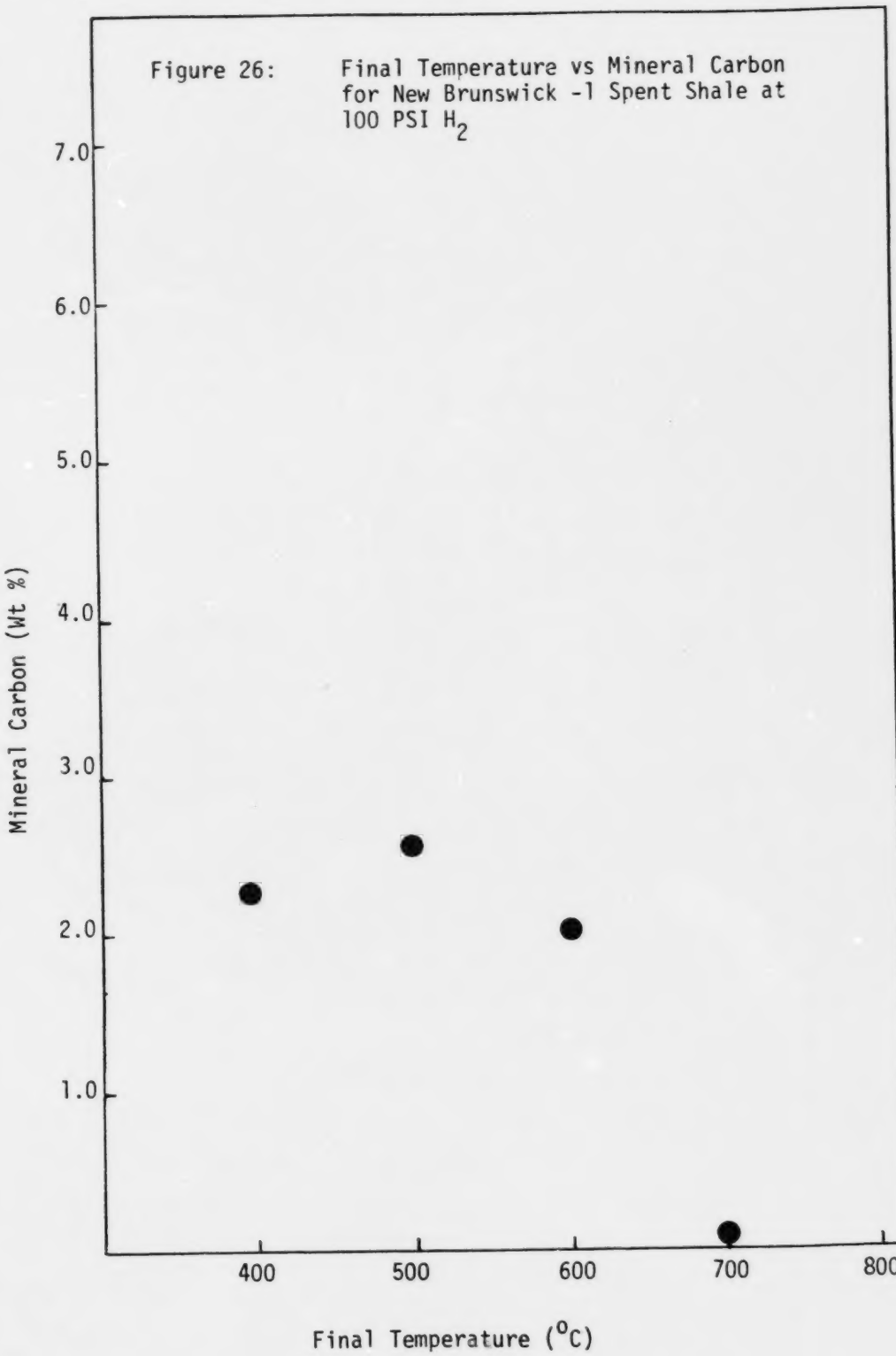


Figure 27: Final Temperature vs Mineral Carbon in New Brunswick -2 Spent Shale at 100 PSI H_2

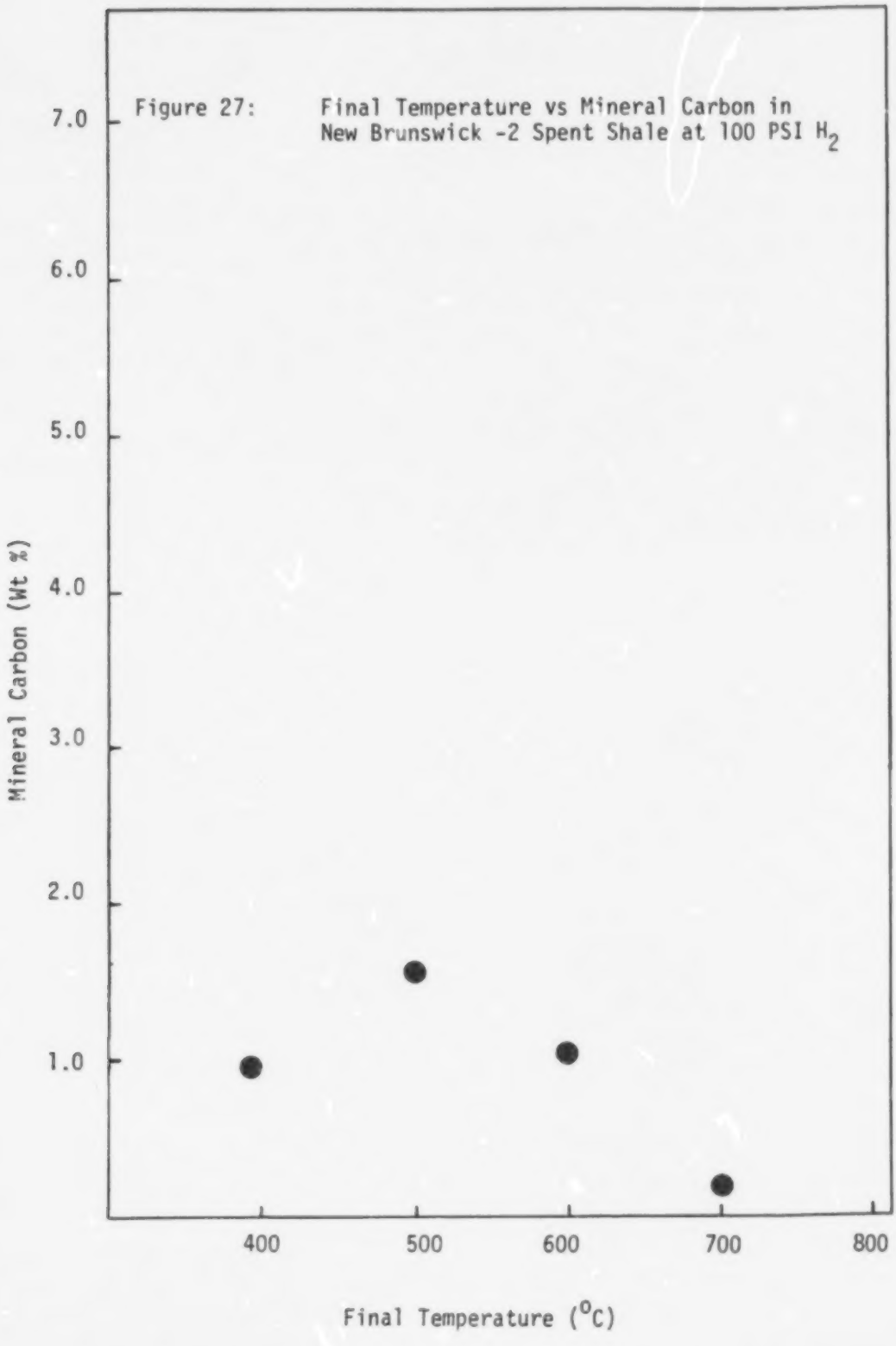


Figure 28: Final Temperature vs Mineral Carbon in Newfoundland 189-10 Spent Shale at 300 PSI H_2

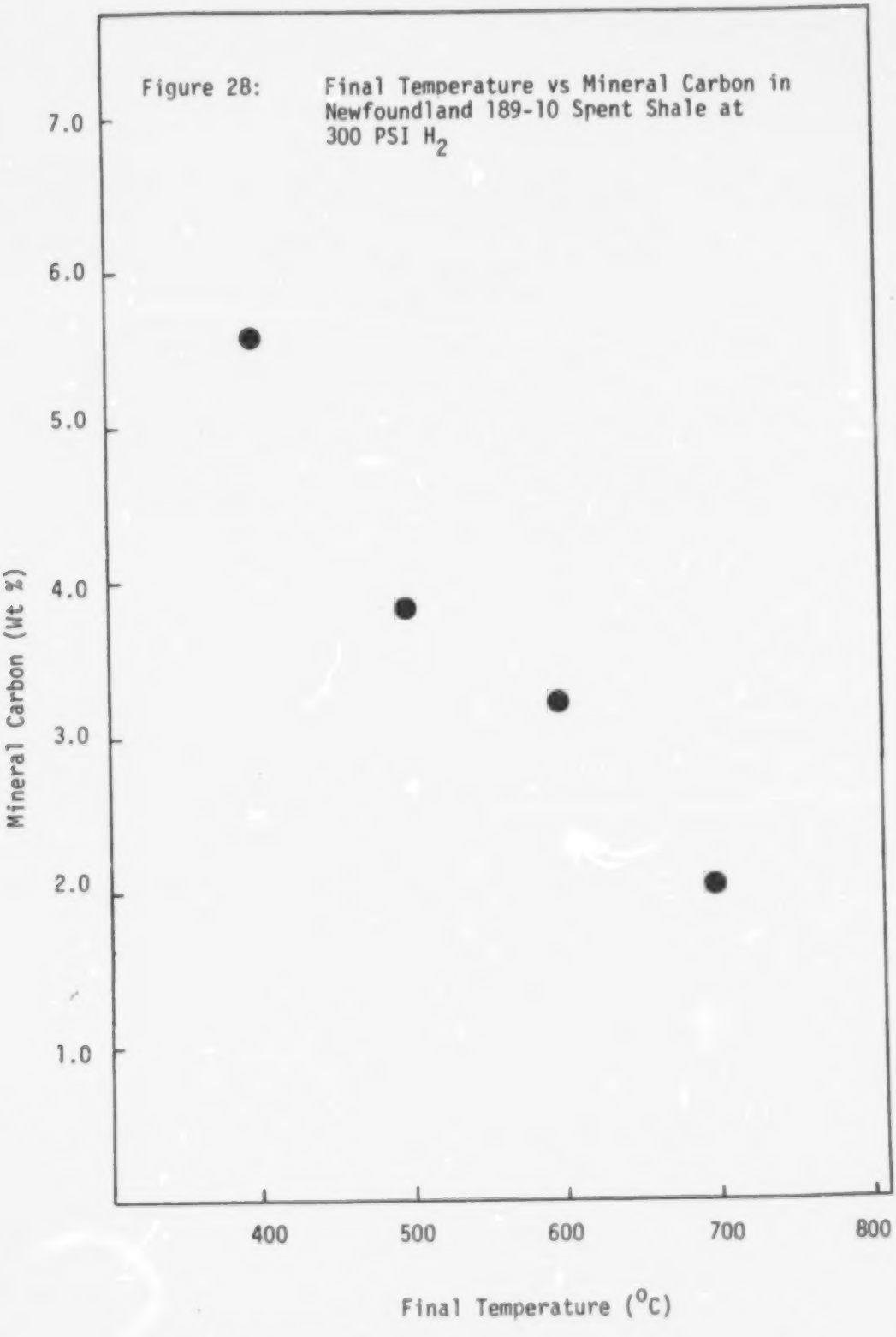


Figure 29: Final Temperature vs Mineral Carbon in Ontario OGS-83-3 Spent Shale at 300 PSI H_2

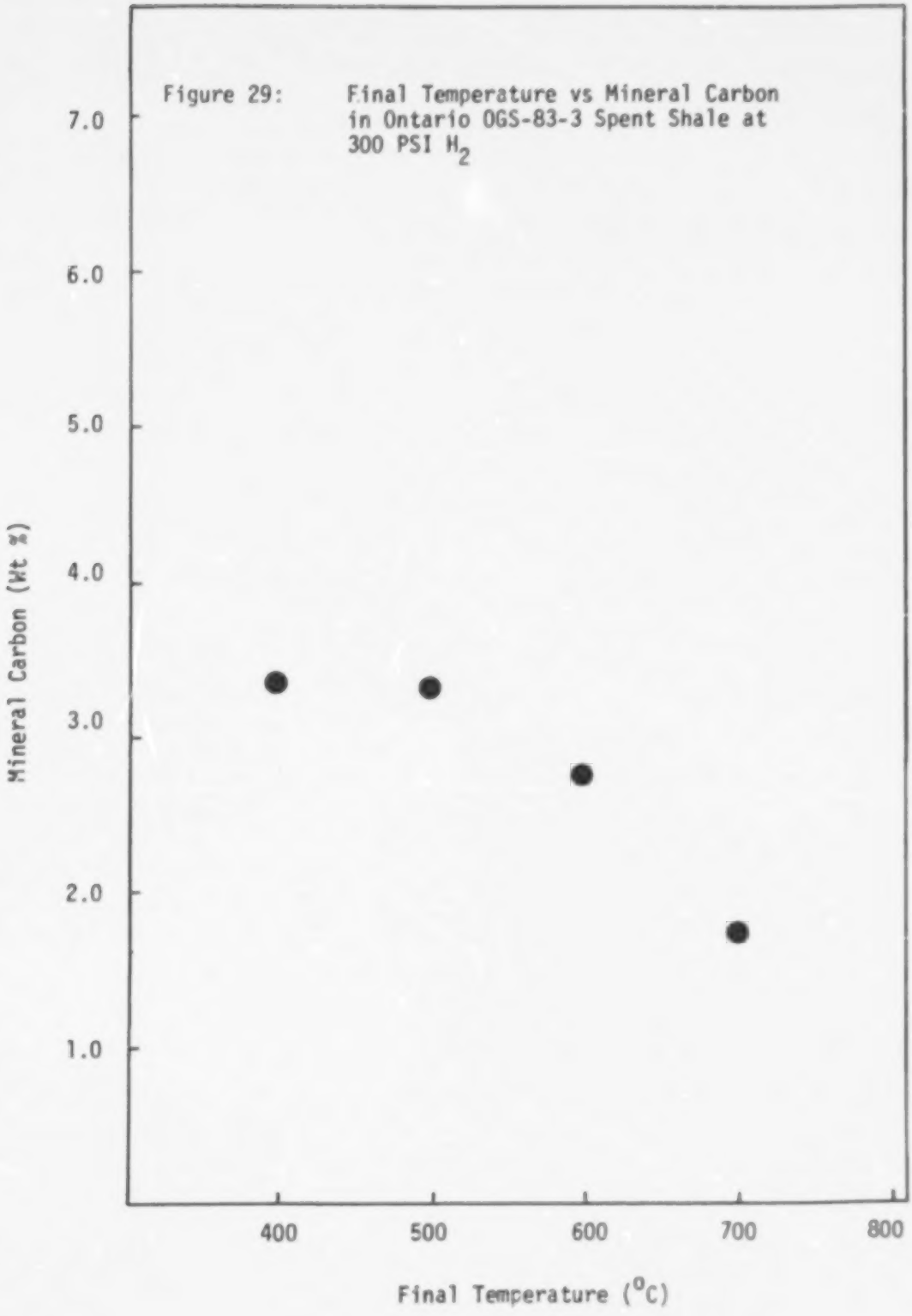
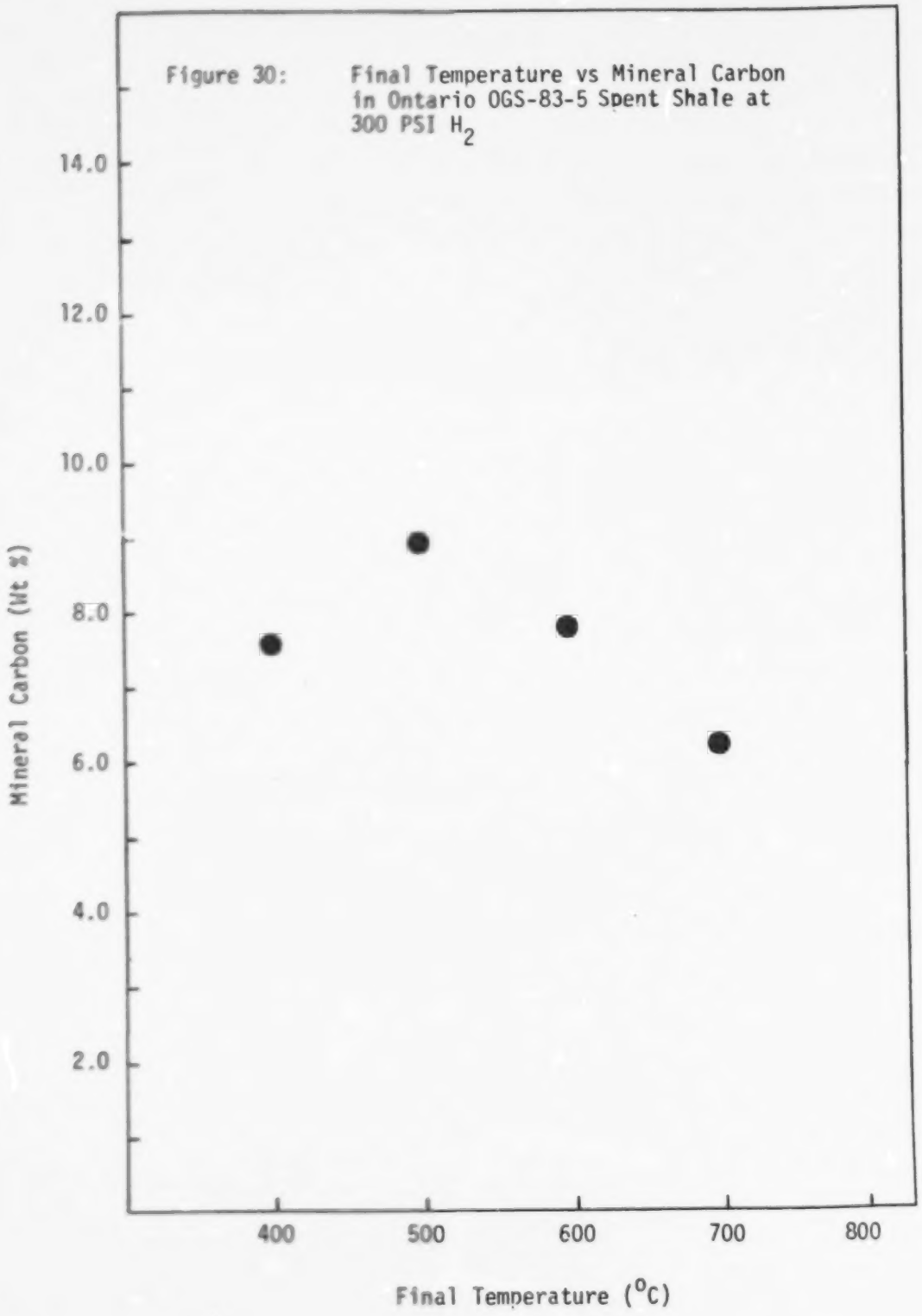


Figure 30: Final Temperature vs Mineral Carbon in Ontario OGS-83-5 Spent Shale at 300 PSI H_2



6.0 CONCLUSION

6.0 CONCLUSION

Hydrogen retorting of the five oil shales increased the oil and gaseous yields over Fischer assay retorting. Generally, for all shales tested, increasing hydrogen pressures had little affect on oil yields, however, increasing final retorting temperatures increased oil and gaseous yields. Organic carbon analysis of the spent shales confirmed the above results. Decomposition of mineral carbon was significant at higher retorting temperatures and formation of CO_2 contributed to increased gas products. Hydrogen retorting increased nitrogen and reduced sulphur in oils. Decreased sulphur in oils was attributed to an increase of sulphur in gaseous products.

7.0 ACKNOWLEDGEMENTS

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The assistance of Dr. E. Furimsky of Energy, Mines and Resources in the procurement of samples and his guidance during the experimental program is recognized with appreciation.

8.0 REFERENCES

8.0 REFERENCES

(1) Brown, G.P. and Abbott, D., 1981, Evaluation of Oil Shale from Eastern Canada by Retorting and by Concentration of a Kerogen-Rich Fraction, CANMET Project Number 420410, RPC Report Number AS/82.

(2) Synnott, J. A. and Salter, R. S., 1983, Modifications of Existing Test Facilities, Optimization of Hydroretorting Conditions and Assessment of Canadian Oil Shales as a Source of Synthetic Fuels. CANMET Project Number 420301, RPC Report Number MDP/83/12.

9.0 APPENDICES

9.1 STATEMENT OF WORK

DSS File: 07SQ.23440-4-9066

APPENDIX "A"

STATEMENT OF WORK

EFFECT OF TEMPERATURE AND HYDROGEN PRESSURE AND LIQUID YIELDS FROM SELECTED OIL SHALES

You shall carry out experimental evaluations in accordance with the following tasks:

Task 1 - Sample Preparation

Obtain about 4 kg of each of the five shale samples (two from New Brunswick, two from Ontario and one from Newfoundland). Grind the samples and sieve to obtain necessary fractions.

Task 2 - Preliminary Characterization

Five samples will be characterized, i.e., two from the province of New Brunswick (Albert formation), two from Ontario (Collingwood formation) and one from Newfoundland. The characterization will include:

- proximate analysis
- carbon (total, organic & carbonate)
- Hydrogen (total and organic)
- sulphur
- nitrogen
- metal oxide content in mineral matter
- Fischer assay
- yields of liquids, water, gases and residue
- elemental analysis of liquids
- spec. gravity of liquids
- proximate analysis of spent shale

Task 3 - Hydrogen Retorting of New Brunswick Oil Shales

- Perform experiments at 500 degrees C and heating rate of 12 degrees C/min at 0, 100, 300, and 500 psi of hydrogen (total of 8 experiments)
- Discuss the results with CANMET Scientific Authority to select the optimal pressure of hydrogen
- Using this pressure of hydrogen and heating rate of 12 degrees c/min perform the experiments at 400 degrees, 500 degrees, 600 degrees and 700 degrees C (total of 8 runs)
- Discuss the results with CANMET Scientific Authority to select the optimal temperature and hydrogen pressure. Under selected conditions perform experiments at the heating rate of 6 degrees C/min and 12 degrees C/min (total of 4 experiments)
- Total of 20 experiments will be performed under this task.

.../2

APPENDIX "A" (Cont'd.)

Task 4 - Retorting of Oil Shales from Ontario and Newfoundland

- Perform experiments at 500 degrees C and heating rate of 12 degrees C/min at hydrogen pressure of 0, 100 and 500 psi (9 runs). Evaluate data and discuss with CANMET Scientific Authority selection of another hydrogen pressure (e.g. 1000 psi). Then perform experiments at this pressure (3 runs)
- Select the optimal pressure and perform experiments at 400 degrees, 500 degrees, 600 degrees and 700 degrees C at heating rate of 12 degrees C/min (12 runs)
- At the optimal temperature and pressure perform the experiments at heating rate of 6 degrees C/min and 12 degrees C/min (6 runs)

In this task total of 30 experiments will be performed.

Task 5 - Analytical Evaluation of Products from Task 3 and Task 4

Spent Shale - Carbon content (total, organic and carbonate)
sulphur
nitrogen
proximate analysis

Liquids - elemental analysis (carbon, hydrogen, nitrogen, sulphur and oxygen by difference)
specific gravity

Task 6 - Preparation of the Final Report

Evaluate the experimental data and make the following correlations:

a. yield of liquids versus hydrogen pressure at 500 degrees C
b. Yield of liquids versus temperature at an optimal hydrogen pressure
c. H/C ratio of liquids versus temperature
d. H/C ratio of liquids versus hydrogen pressure
e. content of organic carbon in spent shale versus hydrogen pressure
f. content of organic carbon content in spent shale versus temperature
g. content of carbonate carbon in spent shale versus temperature

- tabulate all experimental results in a series of tables
- prepare the first draft of the final report and discuss it with CANMET Scientific Authority
- submit final report (10 copies) incorporation the comments of Scientific Authority.

Task 7 - Presentation at EMR

Give an oral presentation in Ottawa to a selected group of EMR staff at the conclusion of Phase 3.

9.2 HYDROGEN RETORTING PROCEDURE

9.2 HYDROGEN RETORTING PROCEDURE

This is the procedure used to retort the five shales at their various conditions.

- If necessary, the preheater/superheater was cooled to less than 50°C using a small air pump.

- The glassware was cleaned with acetone and allowed to dry. Each piece was then weighed and assembled to the apparatus. The Connector/Condenser ball joint was sealed with teflon tape.

- The retort was filled with a weighed amount (75 - 100g) of dried oil shale (105°C for 8 hours).

- The retort was then assembled. The copper gaskets were replaced for each test, and the bolts were greased each time with Never-Seize. They were tightened in a star pattern to avoid uneven tightening and therefore leakage.

- The manual control valve was then closed and the apparatus leak tested with helium. The vent was then hooked up and the system depressurized.

- The apparatus was then purged with H_2 for 10 minutes. The exit line heating tape was heated to 400°C.

- The system was then slowly pressurized to the desired pressure in steps of 100 psi every 2 minutes to allow stabilization. The flow rate was set at operating pressure and allowed to stabilize for 5 minutes.

- The controllers were then programmed for the desired final temperature, heating rate, and holding time at the final temperature (30 minutes).

- Ice was added to the centrifuge tube trap and liquid N_2 placed in the condenser.

- The run was then started by starting the controller programs. During the run, the ice bath and the liquid N_2 in the condenser were continually topped off. The exit valve was generally not adjusted.

- After 30 minutes at the final temperature the flow meter was disconnected and the system purged with N_2 at 200 psi. This blew any oil remaining in the exit line down into the centrifuge tube, taking care not to drive it further out of the centrifuge tube into the condenser. The glassware was then disconnected and the liquid N_2 allowed to boil off. The heating systems were shut off and the oven opened to aid in cooling.

- The glassware was allowed to stand for one hour. Any oil in the exit tube was blown into the centrifuge tube with compressed air. The glassware was then disconnected and each piece weighed. The oil in the centrifuge tube was centrifuged to separate any water. Volumes of oil and water were recorded, and the water drawn off with a syringe. The oil was then placed in a labelled vial.

- When the retort was cool, it was disassembled and the spent shale was placed in a dessicator for one hour, weighed and ground. It was then bagged, sealed, labelled and then sent with the oil for analysis.

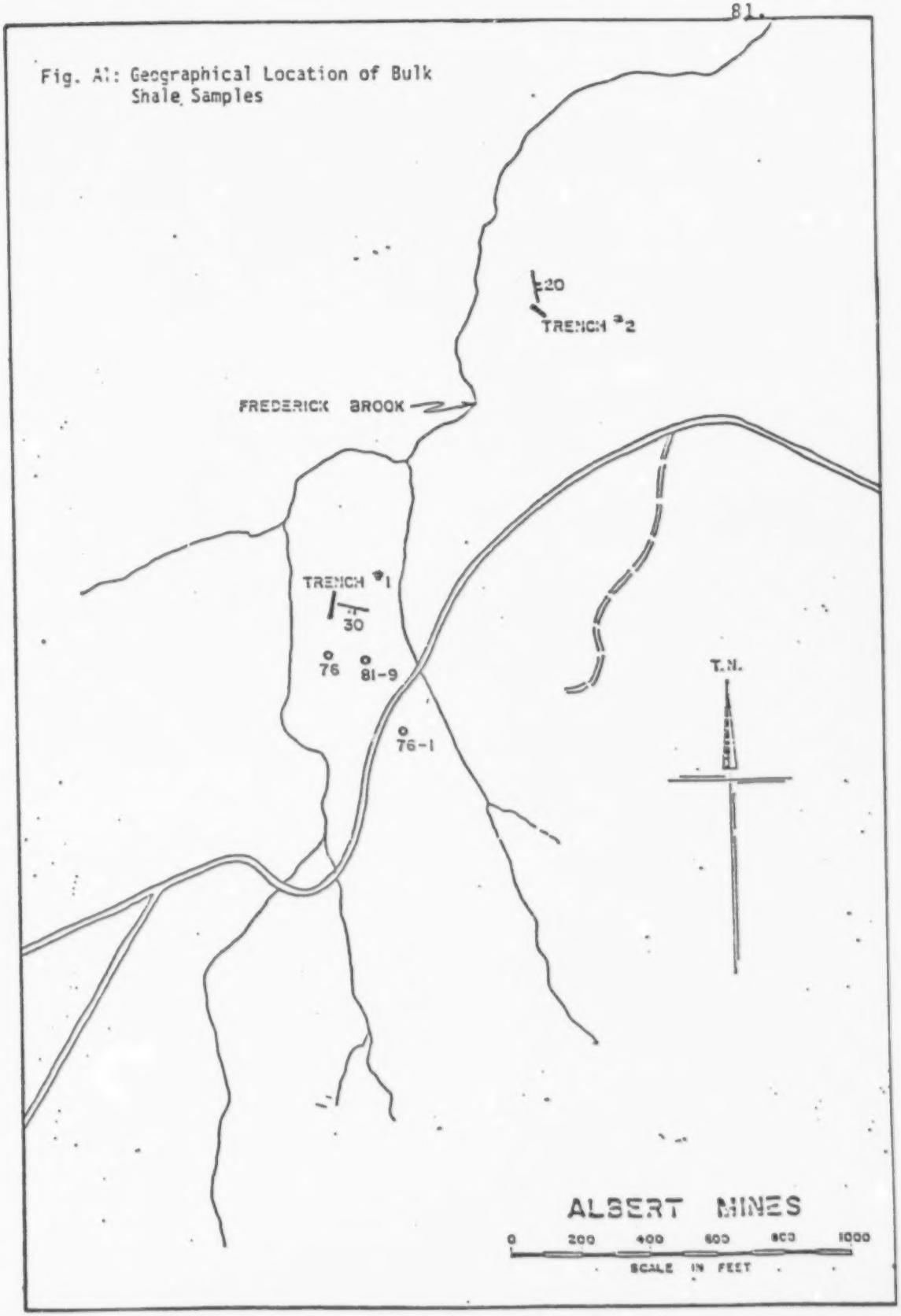
9.3 SHALE ORIGIN AND GEOLOGICAL INFORMATION

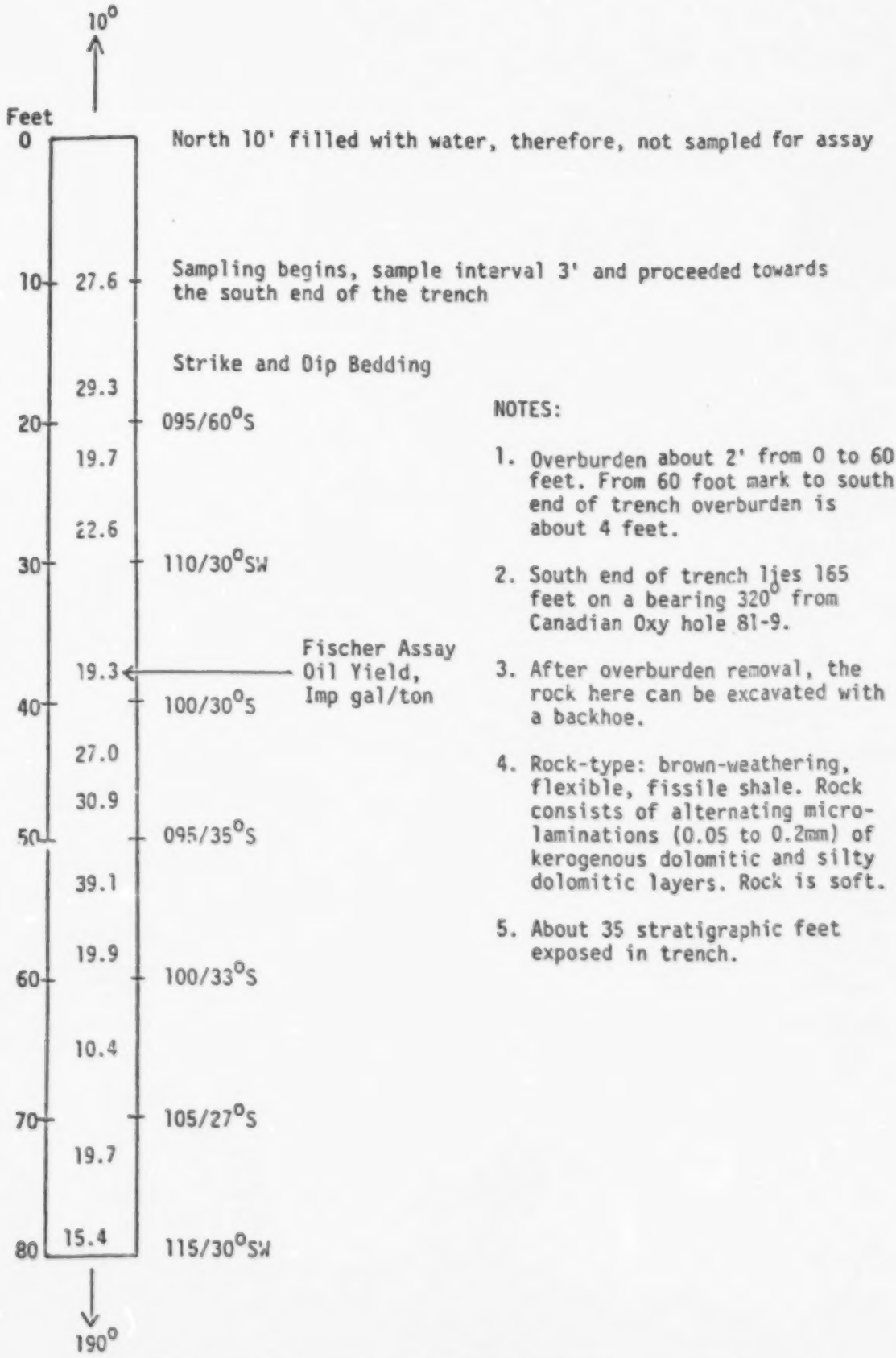
New Brunswick Shale Origin and Geological Information

- Information provided by Mr. Clint St. Peter of Department of Natural Resources, Government of New Brunswick.

The geological location of the two trenches from which bulk samples for the retorting were taken is shown in Fig. A1. Sketches of both trenches together with pertinent geological information are shown in Fig. A2 and A3. Also incorporated in the Figures are the Fischer Assay Oil yield of samples taken at regular intervals along the length of the trench. Shale 1 and 2 referred to in the test correspond to trench 1 and 2 respectively.

Fig. A1: Geographical Location of Bulk Shale Samples



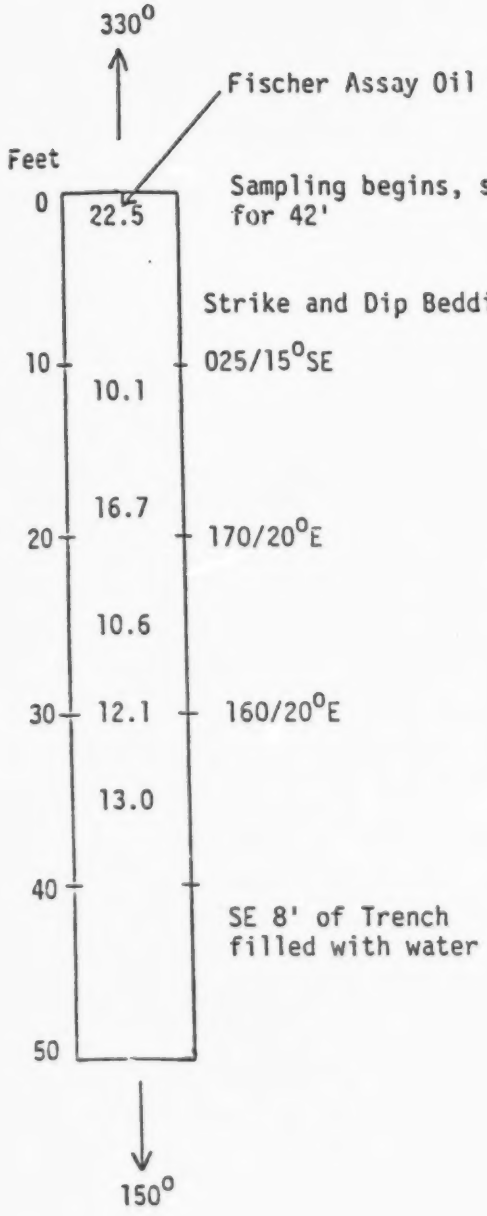


NOTES:

1. Overburden about 2' from 0 to 60 feet. From 60 foot mark to south end of trench overburden is about 4 feet.
2. South end of trench lies 165 feet on a bearing 320° from Canadian Oxy hole 81-9.
3. After overburden removal, the rock here can be excavated with a backhoe.
4. Rock-type: brown-weathering, flexible, fissile shale. Rock consists of alternating micro-laminations (0.05 to 0.2mm) of kerogenous dolomitic and silty dolomitic layers. Rock is soft.
5. About 35 stratigraphic feet exposed in trench.

Fig. A2: Geological and Other Information on Trench No. 1

Trench No. 2



NOTES:

1. Overburden less than 2 feet. Outcrop present on logging road on NW end of trench before trench was opened.
2. After overburden removal, the rock will require ripping before it can be excavated. The rock is too competent to remove by backhoe.
3. Rock-type: Brown-weathering, subfissile silty shale. Rock has 0.5 to 2 mm thick laminations of dolomitic silty shale and dolomitic kerogenous shale. The kerogen laminations are disrupted and discontinuous.
4. About 5 stratigraphic feet exposed in trench.

Fig. A3: Geological and Other Information on Trench No. 2

NEWFOUNDLAND SHALE ORIGIN AND GEOLOGICAL INFORMATION

Information provided by Dr. R. S. Hyde, Department of Earth Sciences, Memorial University of Newfoundland, St. John's, Newfoundland, A1B 3X5.

In the investigation of the economic possibilities of the shale areas, the following method was employed. Channel samples were cut of each bituminous bed. Shale samples were roughly tested in the field by fire test. Each sample from beds three feet and over in thickness, that gave off a smell of oil on heating and ignited either at low or high heat, was kept. These samples were then grouped under the following divisions.

1. Beds over three feet in thickness that ignited and burned readily at low heat.

2. Beds over three feet in thickness that ignited and burned at medium heat.

3. Beds over three feet in thickness that ignited and burned at high heat.

Group #1 - 20 beds, (8 Deer Lake, 8 Humber, 4 Grand Lake), varying from 3 to 5.2' in thickness.

Group #2 - 4 beds, (all on Rocky Brook), varying in thickness between 3 to 5.6'.

Group #3 - 6 beds, (all on Rocky Brook), varying in thickness from 3 to 6'.

The total number of beds selected for further testing was 30. Tests were made on eighteen of these, for volatile matter and moisture combined.

Tests on five for volatile matter, moisture, fixed carbon and ash.

Tests on two for actual Oil Yield.

A ratio between Volatile matter and oil yield was obtained on Deer Lake-Humber River shales and also on Grand Lake shales. The ratio for Deer Lake-Humber River was .63 Imperial gallons per ton for each percent of volatile matter. The ratio for Grand Lake shales was one Imperial gallon per ton for each percent volatile.

The results obtained were as follows: Actual Oil Yield from two samples.

7.5 Imperial gallons per ton. (Deer Lake)
10.5 Imperial gallons per ton. (Grand Lake)

Average percentage of volatile matter - Deer Lake Shales.

(14 Samples) 9.27%

Actual Average Oil Yield (calculated) 5.84 gallons.

Average percentage volatile matter - Humber River Shales

(2 samples) 9.83%

Actual average Oil Yield (calculated) 6.19 gallons.

Average percentage volatile matter - Grand Lake Shales

(3 samples) 10.84%

Average Oil Yield (calculated) 10.8 gallons

Note: A shale to be commercial may be defined as a bed with a thickness greater than three feet, with an actual Oil Yield of more than 16 Imperial gallons per ton, and a yield of Ammonia Sulphate of 50 lbs. per ton.

It is certain that, as far as the investigation of these areas has gone, that no beds, where sampled, gave sufficient Oil Yield to be commercial. Conditions of sedimentation, however, varied greatly over the area and it is possible that other sections of the beds sampled would give a commercial yield.

The throwing out, as far as testing purposes goes, of all shale beds under three feet in thickness, is justified, as a thin bed would have to be very rich to pay. None of the thin beds indicated richness.

The presence of shale beds of the curly variety in the Grand Lake area, taken together with the great thickness of the shale series that is concealed, makes it impossible, without further investigation, to state definitely whether or not this area has commercial possibilities.

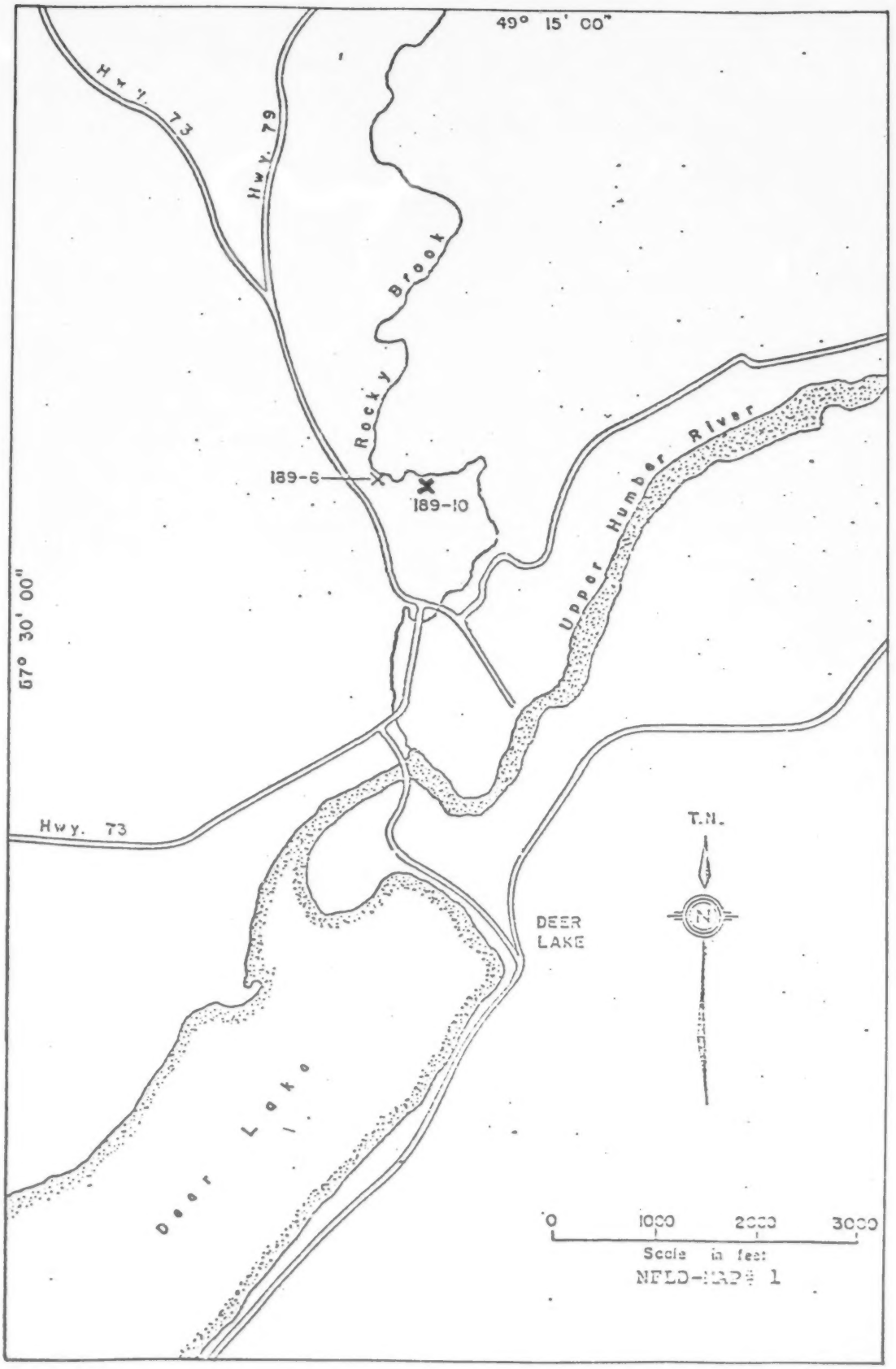
The exposures of the Deer Lake-Humber River series are practically continuous and the most careful work in the field has failed to uncover any high yield bed.

The Grand Lake area is, in the opinion of the writer, more likely to contain beds of commercial value than the Deer Lake-Humber River area.

Conclusions

Thin beds of petroliferous shale of low yield occur scattered through the uppermost part of the section. It is thought from the observations of the outcrops around Deer

Lake and in the Humber valley between the falls that no beds of oil shale of either sufficient thickness of sufficient richness for exploitation occur in the section.


49° 15' 00"
Hwy. 73
Hwy. 79
Rocky Brook
189-6
189-10
Upper Humber River
57° 30' 00"
Hwy. 73
T.N.
DEER LAKE
Deer Lake
0
1000
2000
3000
Scale in feet
NFLD-MAP# 1

Collingwood Formation Samples Drill Hole Locations

Information provided by Jim Sanderson, Engineering and Terrain Geology Section, Ontario Geological Survey, 77 Grenville Street, Room 738, Toronto, Ontario, M5S 1B3.

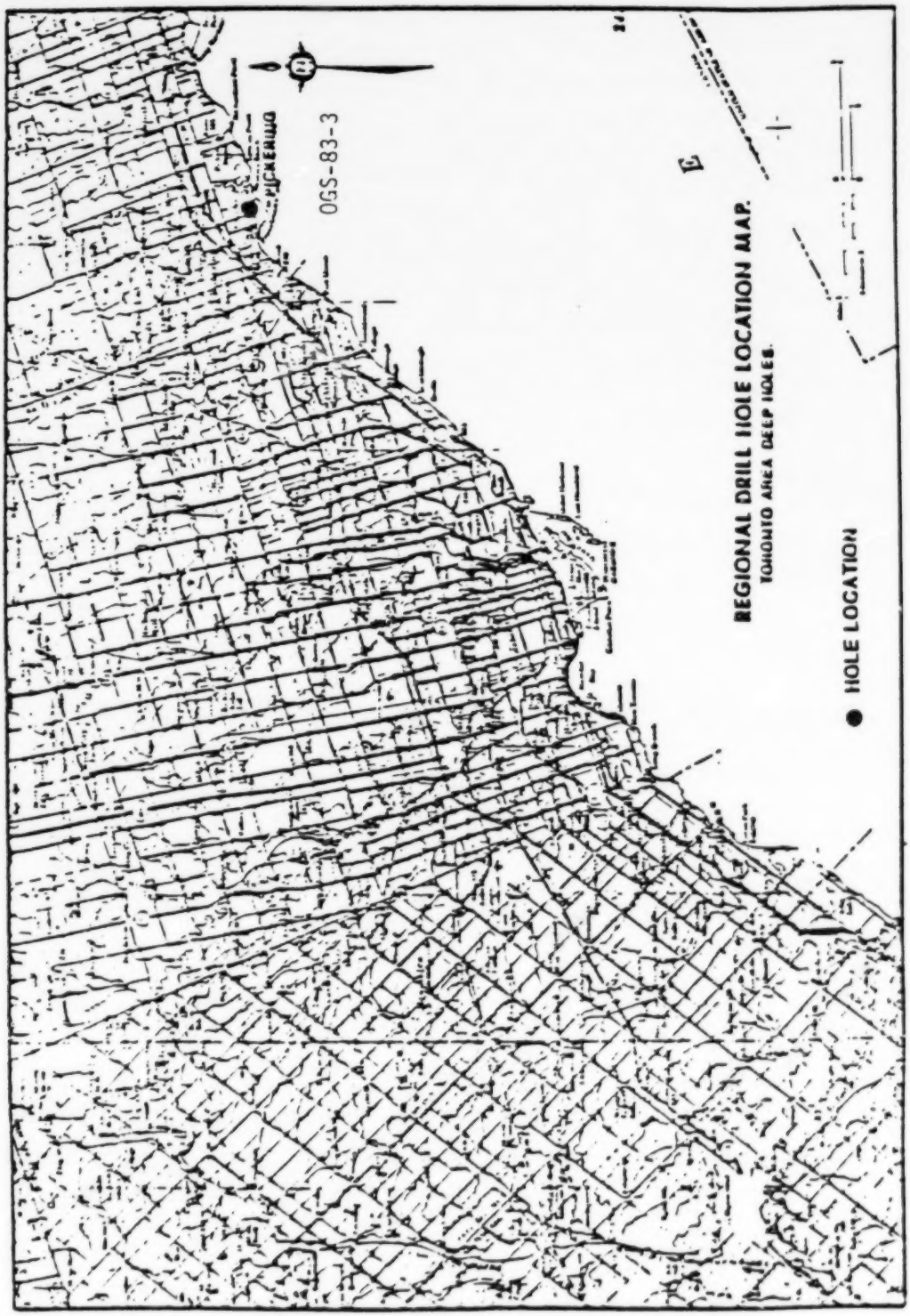
The locations by Lot and Concession are as follows:

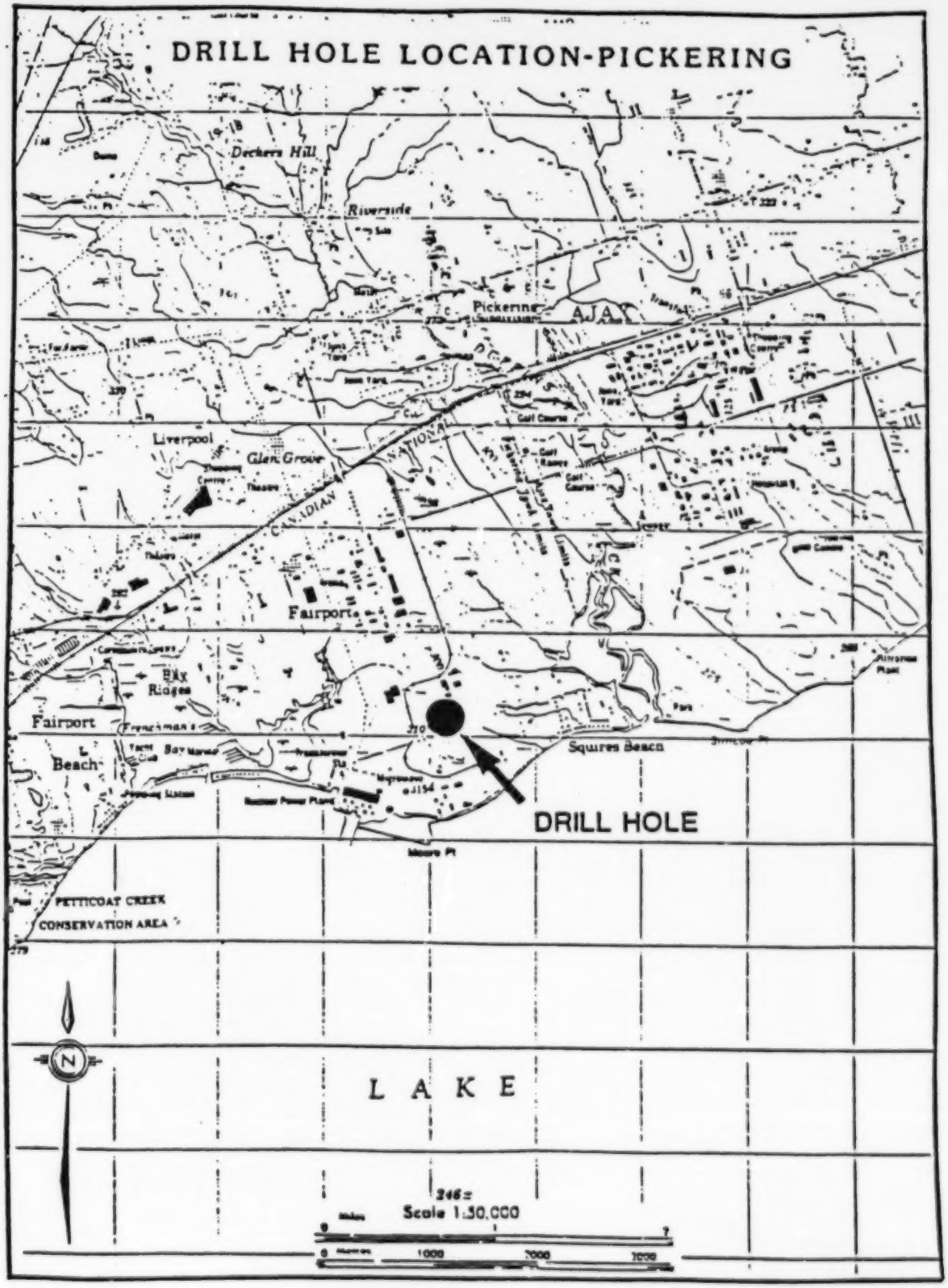
Pickering (OGS-83-3)

County : Durham
Township : Pickering
Lot : 18 Range : 3 Broken Front Concession
46.63 metres north from lot line
191.76 metres east from lot line
Drill Hole Interval : 42.67 m - 45.00 m

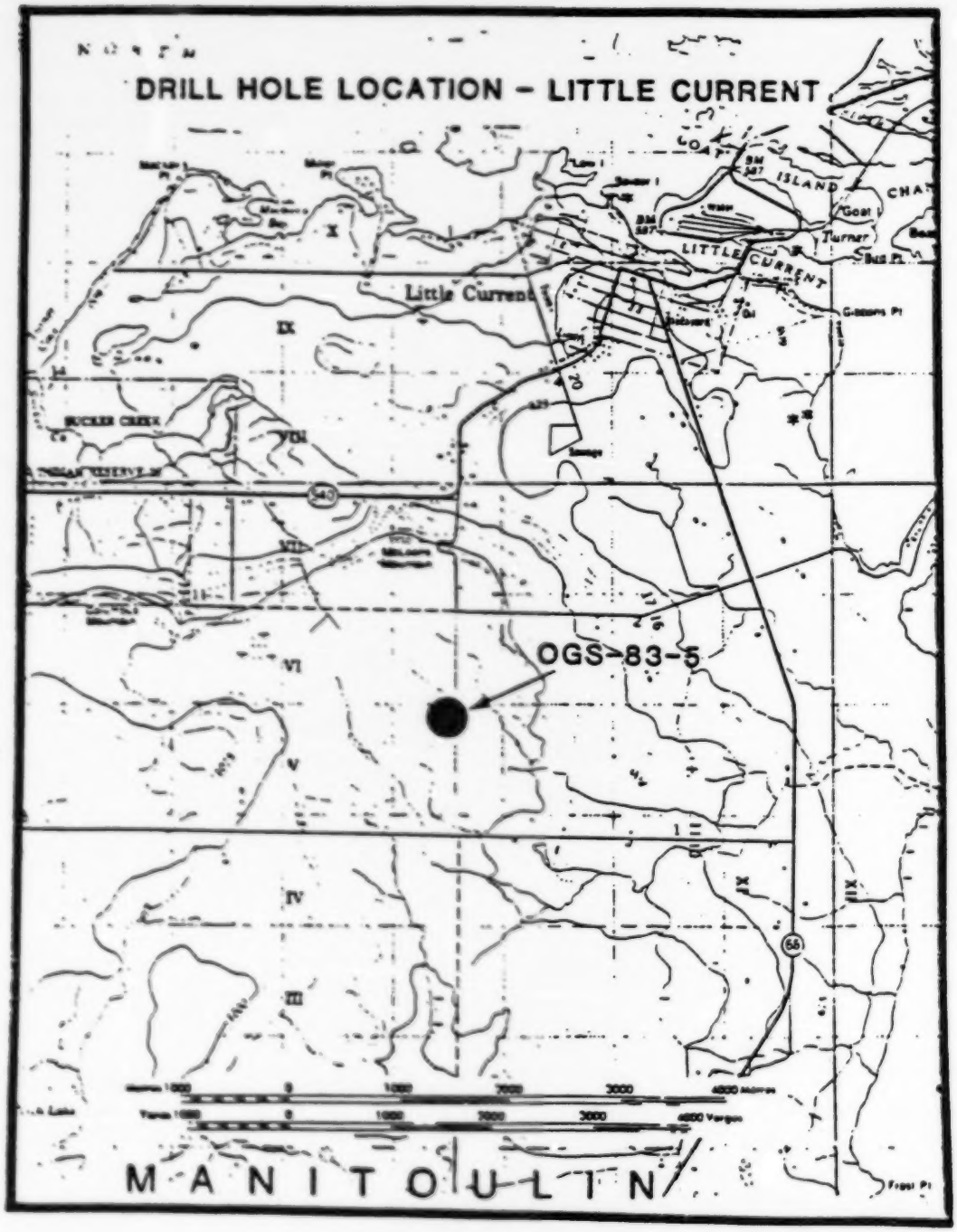
Little Current (OGS-83-5)

County : Manitoulin
Township : Howland
Lot : 6 Concession : V
120.16 metres south from lot line
2.38 metres west from lot line
Drill Hole Interval : 109.18 m - 110.65 m


PICKERING
OGS-83-3
REGIONAL DRILL HOLE LOCATION MAP.
TORONTO AREA DEEP HOLES.
HOLE LOCATION


DRILL HOLE LOCATION-PICKERING
Dockers Hill
Riverside
Pickering
AJAX
Liverpool
Glen Grove
CANADIAN NATIONAL
Fairports
Bay Ridges
Fairport Beach
Squires Beach
DRILL HOLE
PETTICOAT CREEK CONSERVATION AREA
LAKE
246±
Scale 1:50,000

OGS-83-6
LITTLE CURRENT
MANITOULIN ISLAND
N
GEORGIAN
BAY
LAKE HURON
TORONTO
ONTARIO
LAKE ONTARIO
MICHIGAN
SARNIA
LAKE
ST. CLAIR
DETROIT
WINDSOR
LAKE ERIE
KM
HOLE LOCATION


DRILL HOLE LOCATION - LITTLE CURRENT
Little Current
LITTLE CURRENT
ISLAND
OGS-83-5
MANITOULIN

AUTHORIZATION

DEPARTMENT: Mineral Development and Processing

PROJECT TITLE: Effect of Temperature and Hydrogen Pressure on Liquid Yields from Selected Oil Shales

PROJECT NUMBER: 080921

PROPOSAL NUMBER: MDP/84/06

REPORT: MDPP/84/103

Prepared By: John Synnott & Mike Mersereau

Reviewed By: John Synnott

Approved By: Don Abbott

Date: May 22, 1985

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